Hydrogen Virtual Sensors and Performance Optimisation of a Hydrogen Powered Car by Means of Intelligent Technologies

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1 APPENDIX 1 ELECTROLYSER SECTION

1.1 Electrolyser's features.

The features for the electrolyser, such as : head load and coolant requirement, noise specification, operating environment, regulatory conformity, enclosure characteristics, interface connection, remote alarm and shut down specifications, etc… are described as attached in this appendix.

HYDROGEN SPECIFICATIONS		
REQUIREMENT	HOGEN 20	HOGEN 40
Maximum Production Rate (net)	20 SCFH (0.53 Nm^3/h)	40 SCFH (1.05 Nm^3/h)
Maximum Delivery Pressure	200 PSIG (13.8 barg)	200 PSIG (13.8 barg)
Minimum Purity	<5 PPM water <1 PPM other gases	<5 PPM water <1 PPM other gases
WATER SPECIFICATIONS		
REQUIREMENT	HOGEN 20	HOGEN 40
Use Rate	~ 3.0 gallons per 24 hrs (~11.4 liters per 24 hrs)	~6.0 gallons per 24 hrs (~22.7 liters per 24 hrs)
Minimum Quality	ASTM Type II Deionized Water required, ASTM Type I Deionized Water preferred	ASTM Type II Deionized Water required, ASTM Type I Deionized Water preferred
Pressure	20 to 60 PSIG (1.37 to 4.1 barg)	20 to 60 PSIG (1.37 to 4.1 barg)
HEAT LOAD SPECIFICATION		
REQUIREMENT	HOGEN 20	HOGEN 40
Heat Load from Cell Stack	Beginning of Life = 3750 BTU End of Life = 7200 BTU	Beginning of Life = 6800 BTU End of Life = 14,700 BTU
ELECTRICAL SPECIFICATIONS		
REQUIREMENT	HOGEN 20	HOGEN 40
Service Rating	7.2 kVA	12.0 kVA
Electrical Specification	200-240 VAC, 1 phase, 50/60 Hz; consult factory for other	200-240 VAC, 1 phase, 50/60 Hz; consult factory for other
Power Consumed per Volume of Gas Produced	16.5 – 23.7 kWh/100 ft^3 H_2 (6.3 – 9.0 kWh/Nm^3 H_2)	15.5 – 22.8 kWh/100 ft^3 H_2 (5.9 – 8.7 kWh/Nm^3 H_2)
NOISE SPECIFICATION		
REQUIREMENT	HOGEN 20	HOGEN 40
Noise Specification	< 70 dBa	< 70 dBa
OPERATING ENVIRONMENT		
REQUIREMENT	HOGEN 20	HOGEN 40
Location	Indoor, non-freezing, level ± 3°	Indoor, non-freezing, level ± 3°
Ambient Temperature Range	41°F to 104°F (5°C to 40°C)	41°F to 104°F (5°C to 40°C)
Altitude Range	Sea Level to 5000 ft (Sea Level to 1520 m)	Sea Level to 5000 ft (Sea Level to 1520 m)
Ambient Relative Humidity	0 – 95%, non-condensing	0 – 95%, non-condensing
STORAGE ENVIRONMENT		
REQUIREMENT	HOGEN 20	HOGEN 40
Ambient Temperature Range	41°F to 140°F (5°C to 60°C)	41°F to 140°F (5°C to 60°C)
Ambient Relative Humidity	0 – 95%, non-condensing	0 – 95%, non-condensing

CONTROL AND SAFETY FEATURES		
REQUIREMENT	HOGEN 20	HOGEN 40
Standard Features	Fully automated, push button start/stop. Tank filling or load following generation rate available.	Fully automated, push button start/stop. Tank filling or load following generation rate available.
On-Board Ventilation	On-board vent fan draws 750-1000 SCFM fresh air. NFPA 496 Type Z pressurization and purge. EN 1127-1, Clause 6.2.	On-board vent fan draws 750-1000 SCFM fresh air. NFPA 496 Type Z pressurization and purge. EN 1127-1, Clause 6.2.
Other Safety Features	On-board H_2 detection. Automatic fault detection and system depressurization.	On-board H_2 detection. Automatic fault detection and system depressurization.
ENCLOSURE CHARACTERISTICS		
REQUIREMENT	HOGEN 20	HOGEN 40
IP / NEMA Rating	Designed to IP22 / NEMA 3R	Designed to IP22 / NEMA 3R
Volume	38.2" x 30.9" x 41.6" (970 mm x 785 mm x 1056 mm)	38.2" x 30.9" x 41.6" (970 mm x 785 mm x 1056 mm)
Weight	500 lbs (227 kg)	500 lbs (227 kg)
INTERFACE CONNECTIONS		
REQUIREMENT	HOGEN 20	HOGEN 40
H_2 Product Port	Parker ¼" CPI™ compression tube fitting, 316SS	Parker ¼" CPI™ compression tube fitting
H_2/H_2O Vent Port	Parker 3/8" CPI™ compression tube fitting, 316SS	Parker 3/8" CPI™ compression tube fitting
Water Inlet Port	¼" diameter polypropylene plastic tube fitting	¼" diameter polypropylene plastic tube fitting
Water Outlet Port	¼" diameter polypropylene plastic tube fitting	¼" diameter polypropylene plastic tube fitting
REMOTE ALARM AND SHUTDOWN SPECIFICATION		
REQUIREMENT	HOGEN 20	HOGEN 40
Remote Alarm and Shutdown	Form C external alarm (30 VDC/2 A max. rated switching cp), Circuit breaker shunt trip (sub D connector). Circuit insulation is rated for 250 volts	Form C external alarm (30 VDC/2 A max. rated switching cp), Circuit breaker shunt trip (sub D connector). Circuit insulation is rated for 250 volts
STANDARDS AND REGULATIONS SPECIFICATIONS		
REQUIREMENT	HOGEN 20	HOGEN 40
Complies with	CE Registered; EN1050; EN50082-1; NFPA 496; NFPA 50A; NEC 500 Article 501; EN60204-1; EN1127-1; EN60079-10; NFPA 79; EN292-2;	CE Registered; EN1050; EN50082-1; NFPA 496; NFPA 50A; NEC 500 Article 501; EN60204-1; EN1127-1; EN60079-10; NFPA 79; EN292-2;

Table 2: HOGEN 40 Series 2 Hydrogen Generator Specifications

1.2. MATLAB 11 algorithms[1]

[1] The content of this section is referenced from: Howard Demuth, Mark Beale, Martin Hagan, 'Neural network toolbox 6 User's Guide', The Mathworks Inc.

Levenberg-Marquardt (trainlm)

Like the quasi-Newton methods, the Levenberg-Marquardt algorithm was designed to approach second-order training speed without having to compute the Hessian matrix. When the performance function has the form of a sum of squares (as is typical in training feedforward networks), then the Hessian matrix can be approximated as

$$\mathbf{H} = \mathbf{J}^T\mathbf{J}$$

and the gradient can be computed as

$$\mathbf{g} = \mathbf{J}^T\mathbf{e}$$

where **J** is the Jacobian matrix that contains first derivatives of the network errors with respect to the weights and biases, and **e** is a vector of network errors. The Jacobian matrix can be computed through a standard backpropagation technique (see [HaMe94]) that is much less complex than computing the Hessian matrix.

The Levenberg-Marquardt algorithm uses this approximation to the Hessian matrix in the following Newton-like update:

$$\mathbf{x}_{k+1} = \mathbf{x}_k - [\mathbf{J}^T\mathbf{J} + \mu\mathbf{I}]^{-1}\mathbf{J}^T\mathbf{e}$$

When the scalar μ is zero, this is just Newton's method, using the approximate Hessian matrix. When μ is large, this becomes gradient descent with a small step size. Newton's method is faster and more accurate near an error minimum, so the aim is to shift toward Newton's method as quickly as possible. Thus, μ is decreased after each successful step (reduction in performance function) and is increased only when a tentative step would increase the performance function. In this way, the performance function is always reduced at each iteration of the algorithm.

The following code reinitializes the previous network and retrains it using the Levenberg-Marquardt algorithm. The training parameters for `trainlm` are `epochs`, `show`, `goal`, `time`, `min_grad`, `max_fail`, `mu`, `mu_dec`, `mu_inc`, `mu_max`, and `mem_reduc`. The first six parameters were discussed earlier. The parameter `mu` is the initial value for μ. This value is multiplied by `mu_dec` whenever the performance function is reduced by a step. It is multiplied by `mu_inc` whenever a step would increase the performance function. If `mu` becomes larger than `mu_max`, the algorithm is stopped. The parameter `mem_reduc` is used to control the amount of memory used by the algorithm. It is discussed in the next section.

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'trainlm');
net = train(net,p,t);
y = sim(net,p)
```

The original description of the Levenberg-Marquardt algorithm is given in [Marq63]. The application of Levenberg-Marquardt to neural network training is described in [HaMe94] and starting on page 12-19 of [HDB96]. This algorithm appears to be the fastest method for training moderate-sized feedforward neural networks (up to several hundred weights). It also has an efficient implementation in MATLAB® software, because the solution of the matrix equation is a built-in function, so its attributes become even more pronounced in a MATLAB environment.

Try the *Neural Network Design* demonstration `nnd12m` [HDB96] for an illustration of the performance of the batch Levenberg-Marquardt algorithm.

If your network is very large, then you might run out of memory. If this is the case, try `trainscg`, `trainrp`, or one of the conjugate gradient algorithms.

Variable Learning Rate (traingda, traingdx)

With standard steepest descent, the learning rate is held constant throughout training. The performance of the algorithm is very sensitive to the proper setting of the learning rate. If the learning rate is set too high, the algorithm can oscillate and become unstable. If the learning rate is too small, the algorithm takes too long to converge. It is not practical to determine the optimal setting for the learning rate before training, and, in fact, the optimal learning rate changes during the training process, as the algorithm moves across the performance surface.

You can improve the performance of the steepest descent algorithm if you allow the learning rate to change during the training process. An adaptive learning rate attempts to keep the learning step size as large as possible while keeping learning stable. The learning rate is made responsive to the complexity of the local error surface.

An adaptive learning rate requires some changes in the training procedure used by `traingd`. First, the initial network output and error are calculated. At each epoch new weights and biases are calculated using the current learning rate. New outputs and errors are then calculated.

As with momentum, if the new error exceeds the old error by more than a predefined ratio, `max_perf_inc` (typically 1.04), the new weights and biases are discarded. In addition, the learning rate is decreased (typically by multiplying by `lr_dec` = 0.7). Otherwise, the new weights, etc., are kept. If the new error is less than the old error, the learning rate is increased (typically by multiplying by `lr_inc` = 1.05).

This procedure increases the learning rate, but only to the extent that the network can learn without large error increases. Thus, a near-optimal learning rate is obtained for the local terrain. When a larger learning rate could result in stable learning, the learning rate is increased. When the learning rate is too high to guarantee a decrease in error, it is decreased until stable learning resumes.

Try the *Neural Network Design* demonstration `nnd12vl` [HDB96] for an illustration of the performance of the variable learning rate algorithm.

Backpropagation training with an adaptive learning rate is implemented with the function `traingda`, which is called just like `traingd`, except for the additional training parameters `max_perf_inc`, `lr_dec`, and `lr_inc`. Here is how it is called to train the previous two-layer network:

```
p = [-1 -1 2 2; 0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'traingda');
net.trainParam.lr = 0.05;
net.trainParam.lr_inc = 1.05;
net = train(net,p,t);
y = sim(net,p)
```

The function `traingdx` combines adaptive learning rate with momentum training. It is invoked in the same way as `traingda`, except that it has the momentum coefficient `mc` as an additional training parameter.

Resilient Backpropagation (trainrp)

Multilayer networks typically use sigmoid transfer functions in the hidden layers. These functions are often called "squashing" functions, because they compress an infinite input range into a finite output range. Sigmoid functions are characterized by the fact that their slopes must approach zero as the input gets large. This causes a problem when you use steepest descent to train a multilayer network with sigmoid functions, because the gradient can have a very small magnitude and, therefore, cause small changes in the weights and biases, even though the weights and biases are far from their optimal values.

The purpose of the resilient backpropagation (Rprop) training algorithm is to eliminate these harmful effects of the magnitudes of the partial derivatives. Only the sign of the derivative can determine the direction of the weight update; the magnitude of the derivative has no effect on the weight update. The size of the weight change is determined by a separate update value. The update value for each weight and bias is increased by a factor `delt_inc` whenever the derivative of the performance function with respect to that weight has the same sign for two successive iterations. The update value is decreased by a factor `delt_dec` whenever the derivative with respect to that weight changes sign from the previous iteration. If the derivative is zero, the update value remains the same. Whenever the weights are oscillating, the weight change is reduced. If the weight continues to change in the same direction for several iterations, the magnitude of the weight change increases. A complete description of the Rprop algorithm is given in [ReBr93].

The following code recreates the previous network and trains it using the Rprop algorithm. The training parameters for `trainrp` are `epochs`, `show`, `goal`, `time`, `min_grad`, `max_fail`, `delt_inc`, `delt_dec`, `delta0`, and `deltamax`. The first eight parameters have been previously discussed. The last two are the initial step size and the maximum step size, respectively. The performance of Rprop is not very sensitive to the settings of the training parameters. For the example below, the training parameters are left at the default values:

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'trainrp');
net = train(net,p,t);

y = sim(net,p)
```

`rprop` is generally much faster than the standard steepest descent algorithm. It also has the nice property that it requires only a modest increase in memory requirements. You do need to store the update values for each weight and bias, which is equivalent to storage of the gradient.

Fletcher-Reeves Update (traincgf)

All the conjugate gradient algorithms start out by searching in the steepest descent direction (negative of the gradient) on the first iteration.

$$\mathbf{p}_0 = -\mathbf{g}_0$$

A line search is then performed to determine the optimal distance to move along the current search direction:

$$\mathbf{x}_{k+1} = \mathbf{x}_k + \alpha_k \mathbf{p}_k$$

Then the next search direction is determined so that it is conjugate to previous search directions. The general procedure for determining the new search direction is to combine the new steepest descent direction with the previous search direction:

$$\mathbf{p}_k = -\mathbf{g}_k + \beta_k \mathbf{p}_{k-1}$$

The various versions of the conjugate gradient algorithm are distinguished by the manner in which the constant β_k is computed. For the Fletcher-Reeves update the procedure is

$$\beta_k = \frac{\mathbf{g}_k^T \mathbf{g}_k}{\mathbf{g}_{k-1}^T \mathbf{g}_{k-1}}$$

This is the ratio of the norm squared of the current gradient to the norm squared of the previous gradient.

See [FlRe64] or [HDB96] for a discussion of the Fletcher-Reeves conjugate gradient algorithm.

The following code reinitializes the previous network and retrains it using the Fletcher-Reeves version of the conjugate gradient algorithm. The training parameters for `traincgf` are `epochs`, `show`, `goal`, `time`, `min_grad`, `max_fail`, `srchFcn`, `scal_tol`, `alpha`, `beta`, `delta`, `gama`, `low_lim`, `up_lim`, `maxstep`, `minstep`, and `bmax`. The first six parameters have been previously discussed. `srchFcn` is the name of the line search function. It can be any of the functions described in "Line Search Routines" on page 5-26 (or a user-supplied function). The remaining parameters are associated with specific line search routines and are described later in this section. The default line search routine `srchcha` is used in this example. `traincgf` generally converges in fewer iterations than `trainrp` (although there is more computation required in each iteration).

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'traincgf');
net = train(net,p,t);
y = sim(net,p)
```

The conjugate gradient algorithms are usually much faster than variable learning rate backpropagation, and are sometimes faster than `trainrp`, although the results vary from one problem to another. The conjugate gradient algorithms require only a little more storage than the simpler algorithms. Therefore, these algorithms are good for networks with a large number of weights.

Try the *Neural Network Design* demonstration nnd12cg [HDB96] for an illustration of the performance of a conjugate gradient algorithm.

Polak-Ribiére Update (traincgp)

Another version of the conjugate gradient algorithm was proposed by Polak and Ribiére. As with the Fletcher-Reeves algorithm, the search direction at each iteration is determined by

$$\mathbf{p}_k = -\mathbf{g}_k + \beta_k \mathbf{p}_{k-1}$$

For the Polak-Ribiére update, the constant β_k is computed by

$$\beta_k = \frac{\Delta \mathbf{g}_{k-1}^T \mathbf{g}_k}{\mathbf{g}_{k-1}^T \mathbf{g}_{k-1}}$$

This is the inner product of the previous change in the gradient with the current gradient divided by the norm squared of the previous gradient. See [FlRe64] or [HDB96] for a discussion of the Polak-Ribiére conjugate gradient algorithm.

The following code recreates the previous network and trains it using the Polak-Ribiére version of the conjugate gradient algorithm. The training parameters for traincgp are the same as those for traincgf. The default line search routine srchcha is used in this example. The parameters show and epochs are set to the same values as they were for traincgf.

```
net=newff(p,t,3,{},'traincgp');
[net,tr]=train(net,p,t);
```

The traincgp routine has performance similar to traincgf. It is difficult to predict which algorithm will perform best on a given problem. The storage requirements for Polak-Ribiére (four vectors) are slightly larger than for Fletcher-Reeves (three vectors).

Powell-Beale Restarts (traincgb)

For all conjugate gradient algorithms, the search direction is periodically reset to the negative of the gradient. The standard reset point occurs when the number of iterations is equal to the number of network parameters (weights and biases), but there are other reset methods that can improve the efficiency of training. One such reset method was proposed by Powell [Powe77], based on an earlier version proposed by Beale [Beal72]. This technique restarts if there is very little orthogonality left between the current gradient and the previous gradient. This is tested with the following inequality:

$$\left|\mathbf{g}_{k-1}^T \mathbf{g}_k\right| \geq 0.2\left\|\mathbf{g}_k\right\|^2$$

If this condition is satisfied, the search direction is reset to the negative of the gradient.

The following code recreates the previous network and trains it using the Powell-Beale version of the conjugate gradient algorithm. The training parameters for `traincgb` are the same as those for `traincgf`. The default line search routine `srchcha` is used in this example.

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'traincgb');
net = train(net,p,t);
y = sim(net,p)
```

The `traincgb` routine has somewhat better performance than `traincgp` for some problems, although performance on any given problem is difficult to predict. The storage requirements for the Powell-Beale algorithm (six vectors) are slightly larger than for Polak-Ribiére (four vectors).

Scaled Conjugate Gradient (trainscg)

Each of the conjugate gradient algorithms discussed so far requires a line search at each iteration. This line search is computationally expensive, because it requires that the network response to all training inputs be computed several times for each search. The scaled conjugate gradient algorithm (SCG), developed by Moller [Moll93], was designed to avoid the time-consuming line search. This algorithm combines the model-trust region approach (used in the Levenberg-Marquardt algorithm, described in "Levenberg-Marquardt (trainlm)" on page 5-30), with the conjugate gradient approach. See [Moll93] for a detailed explanation of the algorithm.

The following code reinitializes the previous network and retrains it using the scaled conjugate gradient algorithm. The training parameters for trainscg are epochs, show, goal, time, min_grad, max_fail, sigma, and lambda. The first six parameters have been discussed previously. The parameter sigma determines the change in the weight for the second derivative approximation. The parameter lambda regulates the indefiniteness of the Hessian.

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'trainscg');
net = train(net,p,t);
y = sim(net,p)
```

The trainscg routine can require more iterations to converge than the other conjugate gradient algorithms, but the number of computations in each iteration is significantly reduced because no line search is performed. The storage requirements for the scaled conjugate gradient algorithm are about the same as those of Fletcher-Reeves.

One Step Secant Algorithm (trainoss)

Because the BFGS algorithm requires more storage and computation in each iteration than the conjugate gradient algorithms, there is need for a secant approximation with smaller storage and computation requirements. The one step secant (OSS) method is an attempt to bridge the gap between the conjugate gradient algorithms and the quasi-Newton (secant) algorithms. This algorithm does not store the complete Hessian matrix; it assumes that at each iteration, the previous Hessian was the identity matrix. This has the additional advantage that the new search direction can be calculated without computing a matrix inverse.

The following code reinitializes the previous network and retrains it using the one-step secant algorithm. The training parameters for trainoss are the same as those for traincgf. The default line search routine srchbac is used in this example. The parameters show and epochs are set to 5 and 300, respectively.

```
p = [-1 -1 2 2;0 5 0 5];
t = [-1 -1 1 1];
net = newff(p,t,3,{},'trainoss');
net = train(net,p,t);
y = sim(net,p)
```

The one step secant method is described in [Batt92]. This algorithm requires less storage and computation per epoch than the BFGS algorithm. It requires slightly more storage and computation per epoch than the conjugate gradient algorithms. It can be considered a compromise between full quasi-Newton algorithms and conjugate gradient algorithms.

traingd

Algorithm

traingd can train any network as long as its weight, net input, and transfer functions have derivative functions.

Backpropagation is used to calculate derivatives of performance perf with respect to the weight and bias variables X. Each variable is adjusted accordin to gradient descent:

```
dX = lr * dperf/dX
```

Training stops when any of these conditions occurs:

- The maximum number of epochs (repetitions) is reached.
- The maximum amount of time is exceeded.
- Performance is minimized to the goal.
- The performance gradient falls below min_grad.
- Validation performance has increased more than max_fail times since the last time it decreased (when using validation).

1.3 Technical specification of de-ionised water purification system[2]

The de-ionized (DI) water flow rate varies with temperature and pressure. The product quality from a reverse osmosis (RO) unit membrane will decrease if the pressure falls below 200 kPa but this will only shorten the life of the DI cartridge and not affect the final quality of the water.

It is possible to regulate the DI-water temperature and pressure. The temperature will relate to the feed water temperature and we also can change DI water pressure if we want to pump the water into the electrolyser. When the system and the DI water sensors are operated, the pressure and flow rate will be measured. A water pump was installed to satisfy the minimum pressure to feed the water into the system of 20 PSIG (1.37 bars).

[2] This appendix contains the following:

- Email correspondence between Craig Sisson from Ibis Technology and the Mathias Guldager Petersen (HART member).
- Email from Jarrod Coad (Technical Officer at School of Chemistry) in regards to water analysis
- Manual on the Ibis Plus that was provided from the HART group.
- Mathias Guldager Petersen, Installation of a hydrogen generator, HART research report.

Based on the catalogue on plastic hoses, fittings, valves of manufacturer and industrial supplier information, a 3/4bsp tap and pipeline are used to fit DI water purification system. The DI water system was connected to electrolyser by a 7/8 UNC PP tube fitting and a 2m flexible plastic hose, while the 1m hose was connected between the system and the tank. The excess water was drained with a 2m hose.

The system will turn off when the product flow is stopped but the system design does not want it to be continually switching on and off. Therefore, a storage tank of 20 liters was also installed.

Upon the completion of DI water installation, the DI water quality was tested. Sample 1 had a conductivity of 2.12 uS and sample 2 had a conductivity of 56.9 uS.

As mentioned, the electrolyser uses pure water to produce hydrogen. The inlet and outlet of the water is shown in figure 20. The following section provides a description on how the requirements for the feed water are met. Below are details of technical specifications that were referenced from research report on installation of a hydrogen generator written by Mathias Guldager Petersen (HART member).

1.3.1 Requirements and recommendations for the de-ionized feed water

The electrolyser uses approximately 0.5 liters of de-ionised water per hour to produce hydrogen and actively cool the cell stack. The pressure of the feed water needs to be between 137 and 410 kPa and the temperature between 5 and 35°C.

The electrolyser requires a minimum of ASTM Type II de-ionised water. However ASTM Type I is recommended because the life of the guard bed cartridge and the cell stack will be extended be using a higher quality of water. The requirements for ASTM Type I and II are shown in table below.

	ASTM Type I	ASTM Type II
Conductivity at 25°C, max., [μS/cm]	0.056	1.0
Resistivity at 25°C, min., [MΩ-cm]	18	1.0
Total organic carbon (TOC), max., [μg/L]	50	50
Sodium, max., [μg/L]	1	5
Chlorides, max., [μg/L]	1	5
Total silica, max., [μg/L]	3	3

Table: Extract from Standard Specification for Reagent Water.

1.3.2 Selecting procedure for supplying feed water

After some initial research the choice came down to three possibilities for supplying de-ionised water. Namely, getting water from School of Chemistry at UTAS or buying either a Ibis Plus Water Purification System from Ibis Technology, or a Direct-Q Water Purification System from Millipore. The characteristics of the three options are shown in table below.

Options	Price	Quality	Additional remarks
School of Chemistry	Free	ASTM Type II TOC ~ 50 μg/L	The resistivity is a bit below the required 1.0 MΩ-cm
Ibis Plus	1000 AUD	ASTM Type II TOC ~ 50 μg/L	TOC is probably ok, system goes directly on tap, from Australia
Direct-Q	7500 AUD	ASTM Type I TOC < 30μg/L	Directly from tap, monitoring of temperature, pressure and resistivity

Table: Characteristics of different options for supplying de-ionised water.

School of Chemistry was only able to produce water with a resistivity of 0.81 MΩ-cm due to a leakage in their mixed bed deionizer at the time. Furthermore, should they mend the deionizer it would still be problematic to transport the water from School of Chemistry to the Hydrogen Laboratory every time it is needed. For these reasons this option was quickly ruled out. Thus, the choice came down to whether to buy the Direct-Q or the Ibis Plus.

In the end, it was decided to purchase the Ibis Plus. This decision was based on the fact that this system met the requirements while remaining reasonable cheap in comparison to Direct-Q. Furthermore, it was decisive that the Ibis Plus was made by an Australian Company and the transportation time would therefore be relatively short. However, by choosing Ibis Plus rather than Direct-Q, the option of getting ASTM Type I had to be given up.

1.3.3 Description of water purification system

The Ibis Plus water purification system consists of a pre-filter, a carbon filter, a reverse osmosis unit (RO-unit), a water tank, a water pump and a deionizer unit (pure-one polisher). A schematic of the Ibis Plus water purification system is shown in figure 24, while the actual system is shown in figure below.

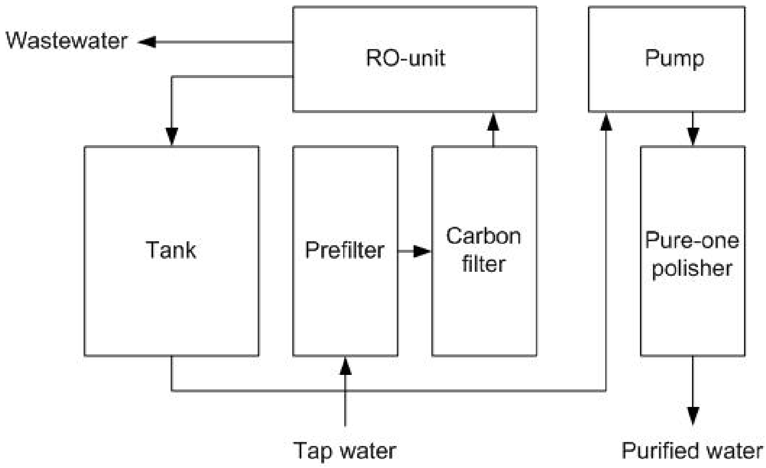


Figure: Schematic of the Ibis Plus water purification system.

Pre-filter

The pre-filter is the first component of the water purification system. It is connected directly to a cold water tap by a polypropylene tube. The pre-filter, which has a mesh of 5 µm, removes the relatively big particles from the water in order to protect the RO membrane.

Carbon filter

The carbon filter is acting as an organic scavenger. It is designed to remove naturally occurring organic contaminants – mainly humid and folic acids. By removing these weakly ionized compounds the RO-unit is protected.

Reverse osmosis unit

The RO-unit removes more than 95% of the dissolved salts from the feed water and more than 99% of other contaminants such as organics and bacteria. In short, RO is the process by which water molecules are forced through a very thin semi-permeable membrane by water pressure. Long sheets of the membrane are ingeniously sandwiched together and rolled up around a hollow central tube in a spiral fashion. This rolled-up configuration is commonly referred to as a spiral wound membrane. The water pressure from the tap supplies the energy to force the water through the membrane, separating it from unwanted substances. In the RO-process the substances left behind are automatically diverted to a waste drain so they do not build up in the system. This is accomplished by using a part of feed water to carry away the rejected substances to the drain, thus keeping the membrane clean.

Water tank

The purification system will turn off when the product flow is stopped. However, the system produces pure water at a rate of 6 liters per hour, while the electrolyser uses 0.5 liters per hour. It is therefore necessary to introduce water storage between the system and the electrolyser, so that the purification system does not need to be continually switching on and off.

The tank is made of polypropylene and it stores 20 liters. It has an inlet in the top for a ¼” tube and a tap in the bottom for a ½” tube. Furthermore, it has a float valve connected to the inlet, which shuts off the water when the tank is almost full.

DI water pump

A water pump is connecting the tank and the pure-one polisher in order to supply the electrolyser with a minimum pressure of 137 kPa. The pump is a 6800 RO Booster Pump from Aquatec. It has an adjustable pressure output and the maximum delivery pressure is 125 psi (860 kPa). The pump is specifically made for RO-systems. The pump is connected to a pressure switch, which insures a delivery pressure of 40 psi (275 kPa).

Pure-one polisher

The pure-one polisher is a combination of an ion-exchange resin (deionizer) and an organic scavenger. The deionizer consists of tiny spherical plastic beads through which the feed water passes. It functions by exchanging hydrogen ions for cationic contaminants and hydroxyl ions for anionic contaminants in the feed water. The organic scavenger is similar to the one described above. It has however, a finer mesh. It is capable of removing the organic material down to a total content (TOC) of approximately 50 μg/L.

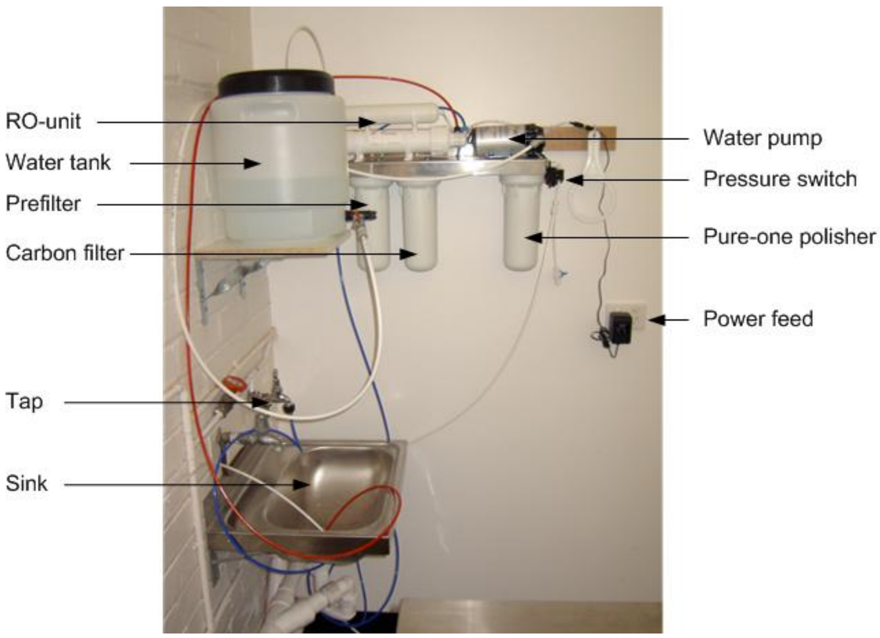


Figure: Ibis Plus water purification system.

1.3.4 Measurement of the water quality

Because Ibis Technology could not guarantee how good the water quality would be it was decided to perform a water analysis with regards to the resistivity. This analysis was conducted by Jarrod Coad from School of Chemistry. The result showed a resistivity of 0.47 MΩ-cm. This is below the required 1.0 MΩ-cm. However, it is known that the water quality goes down if the water gets in contact with air, which was the case during the filling into a plastic container. The water was also left in a container over night, which could have potentially resulted in contamination.

1.3.5 Waste water

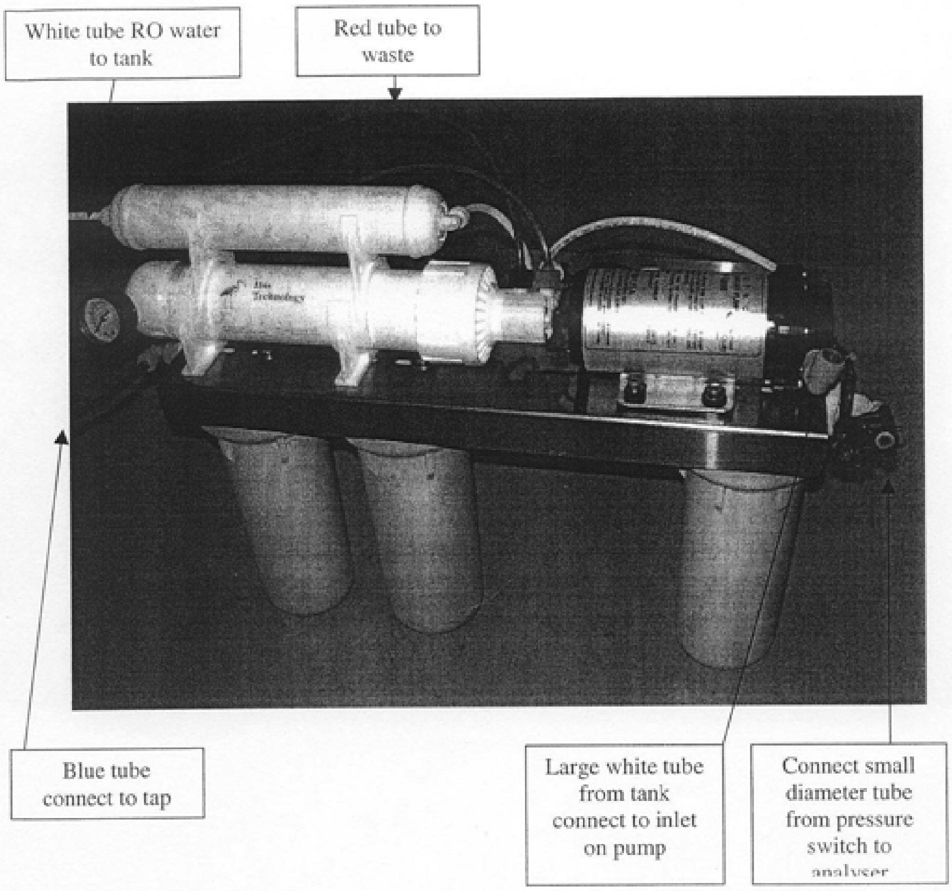
Waste water from the water purification system and from the electrolyser also had to be handled. It was decided that all wastewater would be directed into the sink with the use of polypropylene hoses as shown in figure 25. It is important to note that the drain line from the electrolyser must under no circumstances be obstructed, as this can result in permanent damage.

Instruction Manual for Ibis Plus low organic

Laboratory water purification system

1. Description

A combination of purification technologies is used to provide high purity water suitable for most laboratory applications. The systems comprise carbon/depth prefiltration, a high performance RO membrane, and a mixed bed ion-exchange cartridge that contains organic scavenger resin. The system may be wall mounted or will stand on a bench. The float valve supplied may be installed in any suitable tank to provide automatic operation and the convenience of larger quantities of high purity water on tap.


White tube RO water to tank
Red tube to waste
Blue tube connect to tap
Large white tube from tank connect to inlet on pump
Connect small diameter tube from pressure switch to analyser

JG John Guest

John Guest has a long established reputation as a world leading manufacturer of push-in fittings. This reputation is built on producing consistently high quality products with an ongoing commitment to both value engineering and product development. John Guest has been an ISO 9001 registered manufacturer since 1989.

Super Speedfit push-in fittings have been designed for a wide range of industrial applications. They provide a fast and secure way of connecting tubes and offer considerable advantages over conventional fittings.

Complex tubing systems can be assembled more rapidly than with traditional methods and because Super Speedfit fittings are easy to disconnect, fault finding and maintenance become a much easier operation.

The products in this brochure are produced in F.D.A. approved materials making them especially suitable for food quality applications.

- Suitable for inert gases, liquids and vacuum
- Fast installation time 'right first time every time'
- Suitable for metal or plastic tubes
- No tools needed
- Quick Disconnection
- Can be re-used many times
- Superior flow characteristics
- Wide ranges of sizes and configurations
- Collet Covers prevent accidental removal of tube and allow colour coding
- Fittings are produced in Food and Drug Administration (FDA) approved materials
- Quality manufacture - John Guest has been an ISO 9001 manufacturer since 1989
- NSF 51 Certified - suitable for contact with foodstuffs
- NSF 61 Certified - suitable for use in potable water systems

NSF APPROVED FDA MATERIAL ISO 9001

SK 266-001

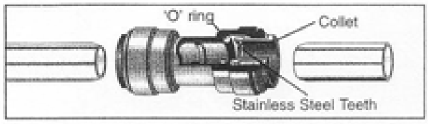
Materials of construction

Super Speedfit fittings are made up of three components:
Bodies are produced in an acetal copolymer or polypropylene.
'O' rings are nitrile rubber or EPDM.
Collets are produced in acetal copolymer or polypropylene with stainless steel teeth.

How to make a connection

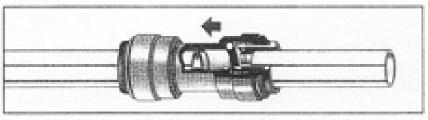
To make a connection, the tube is simply pushed in by hand; the unique patented John Guest collet locking system then holds the tube firmly in place without deforming it or restricting flow.

1 Cut tube square



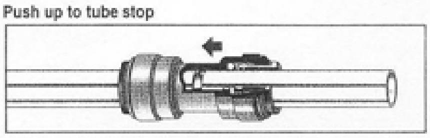
Cut the tube square. It is essential that the outside diameter be free of score marks and that burrs and sharp edges be removed before inserting into fitting. For soft or thin walled plastic tubing we recommend the use of a tube insert.

2 Insert tube



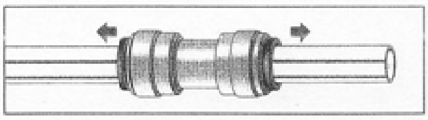
Fitting grips before it seals. Ensure tube is pushed in to the tube stop.

3 Push up to tube stop



Push the tube into the fitting, to the tube stop. The Collet (gripper) has stainless steel teeth which hold the tube firmly in position while the 'O' ring provides a permanent leakproof seal.

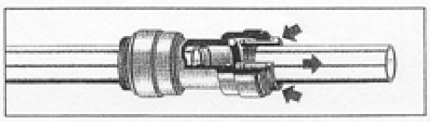
4 Pull to check secure



Pull on the tube to check it is secure. It is good practice to test the system prior to leaving site and/or before use.

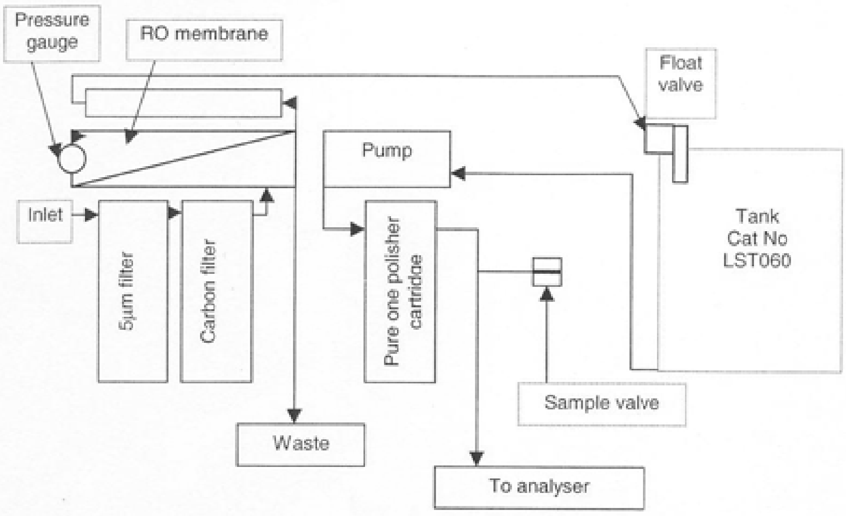
Disconnecting

Push in Collet and remove tube



To disconnect, ensure the system is depressurized before removing fitting. With the Collet held in this position, the tube can be removed. The fitting can then be re-used.

2. Flow Schematic Ibis Plus Uni of Tasmania



3.Installation

3.1 Location

Locate the unit within 2 metres of a suitable cold water supply and within 2 metres of a suitable waste outlet such as a sink or tun-dish. Care should be taken when choosing the site to ensure that it is not located near any electrical equipment as water spillage that occurs when changing the cartridges may create a hazard.

3.2 Cold water supply

The system should be connected to a cold water supply that can supply a minimum of 35 psi inlet pressure. The inlet fitting supplied is to suit a 3/4" BSP tap. This is the most common size of threaded tap. To adapt this to other fittings the appropriate adaptor will be available from hardware or plumbing suppliers.

3.3 Use of the float valve

The system may used with or without the float valve supplied. The float valve will enable the system to operate unattended and ensures that your tank is kept full. If you do not wish to use the float valve a garden tap timer may be used to ensure that the system is not accidentally left on and your tank overflows.

3.4 Tubing Colours

Blue = Inlet to be connected to the tap.

Red = Waste to go down the drain.

White = Product to go into the tank for laboratory use.

4. Installation Procedure

4.1 Connect the inlet fitting on the blue tube to the appropriate cold water tap.

4.2 Place the red waste tube in the sink waste or other suitable waste outlet.

4.3 Connect the white product tube from the RO assembly to the float valve on the top of the tank.

4.4 The system is now ready for use. Turn on the tap slowly until full flow and pressure are achieved.

4.5 Water will begin to be produced by the system but it may be a few minutes before water starts to flow into your tank as the water needs to first fill the system.

4.6 Take note of the pressure gauge reading or mark the needle position with a marker pen for future reference.

4.7 Once the tank is full connect the larger diameter tube from the tap on the tank to the inlet of the pressure pump and connect the smaller diameter tube from the polisher cartridge to the analyser.

4.8 Open the valve at the tank, plug in the power supply to the pump and switch on the power.

4.9. Water will now be pumped to the analyser.

5. Maintenance Plus low organic system

5.1 Consumable ordering information

PF1005	Prefilter 5µm Ibis Plus
CT1005	Carbon prefilter Ibis Plus
DIMN1000	Ion exchange/organic cartridge 10"
R00035	RO membrane 6 litre per hour

5.2 Changing the prefilter
This prefilters should be changed every 1 to 3 months. The prefilters not only remove particulates from the feed water but also chlorine. Chlorine in the feed water can drastically shorten the life of the RO membrane. Where the feed water has a high particulate load it may be necessary to change the prefilters more often. This will be indicated when the prefilter is completely brown

To change the prefilters, turn off the inlet water at the tap and wait for about wait for the pressure gauge to drop to 0. If the system is not running push the float valve down to relieve the pressure in the system. Unscrew the prefilter housing bowl by grasping the bowl and turning anti-clockwise. Remove and discard the old prefilters. Insert the new prefilters with the narrowest section (carbon filter) in the bottom of the housing and replace the housing taking care that the top of the filter fits into the housing head.

5.3 Monitoring the product water

The product water should be monitored on a regular basis to ensure the system is producing water of suitable purity. This can be achieved by using a hand held conductivity meter that will measure down to 1µs or below or an in-line conductivity monitor such as Ibis Cat No LSQM04 or by adding some of the water to silver nitrate solution and observing for precipitation.

5.4 Monitoring the product with a portable conductivity meter

Care should be taken when monitoring the product with a portable or desk top conductivity meter in that high purity water quickly absorbs carbon dioxide from the air increasing the conductivity of the water. Measurements should always be taken with running water direct from the system. Measurements done in this manner will give readings less than 0.3 µs/cm with new cartridges installed. If this is not possible or if water from the tank is measured allowance needs to be made for the absorption of CO_2 and readings of 2 to 3 µs/c~~m will b~~e obtained.

5.5 Changing the Ion-exchange cartridge

A set point for the changing of the ion-exchange cartridge needs to be decided on. This is typically about 1µs/cm for in-line measurements or 3 µs/cm for tank measurements. When the conductivity of the product water rises above your chosen set point it is necessary to fit a new ion-exchange cartridge Cat No DIMN1000. The ion-exchange cartridge is the right hand side housing. Turn off the water at the tank and turn off the pump. Let the pressure out of the system using the sample valve. Unscrew the housing bowl remove and discard the old cartridge and then install a new cartridge ensuring that the spigot is pushed all the way into the housing head. Replace the housing bowl on the system and it is now ready for use.

5.6 Monitoring the performance of the Reverse Osmosis (RO) membrane

If desired the performance of the RO membrane can be monitored. The RO membrane will remove >95% of the dissolved salts from the feed water and >99% of the organics. The amount of dissolved salts removed by the membrane is called the *salt rejection*. The performance of the RO membrane can be checked with a suitable conductivity meter. Two other important parameters are the quantity of product water and the quantity of waste water. These parameters are checked before the systems leave the factory. However as these parameters vary from membrane to membrane and are dependent on the local water pressure it is advisable to measure these parameters to obtain baseline readings for your system in your location.

5.7 Measuring the salt rejection of the RO membrane

Measure the conductivity of the feed water using an appropriate conductivity meter. Disconnect the white tubing that runs from the RO membrane housing to the ion-exchange cartridge housing at the ion-exchange housing by pushing in the ring around the tubing and withdrawing the tubing. After the system has been running for a least 10 minutes measure the conductivity of the RO product water.

Calculate the salt rejection as follows;

$$\text{Salt Rejection (\%)} = \frac{\text{feed conductivity - product conductivity}}{\text{feed conductivity}} \times \frac{100}{1}$$

The salt rejection of the RO membrane should be > 95% at 60 psi feed pressure. The salt rejection of the RO membrane is dependent on the feed pressure. At feed pressures of less than 60 psi the salt rejection may well drop below 95% while higher pressures may give improved performance. Should the RO membrane be achieving less than the specified amount, it may be possible to service the membrane or it may need to be replaced.

5.8 Servicing the RO membrane
Please contact Ibis Technology or your distributor for information on servicing the membrane.

5.9 Replacing the RO membrane
To replace the RO membrane;

Turn off the feed water at the tap.

If the float valve is being used drain some water out of the tank below the level of the float valve and wait for about 1 minute to de-pressurise the down stream side of the membrane.

Lift the membrane housing out of the two support brackets.

Unscrew the nut holding the blue tubing that runs from one end to the other of the housing at the right hand end and pull out the tubing just at that end.

Unscrew the bowl from the head of the housing taking care not kink any of the tubing.

Remove the old RO membrane taking care to note the correct orientation of the membrane in the housing.

Install the new membrane with the same orientation as the original membrane.

Replace the blue tubing by inserting the tubing in the socket and screwing the nut finger tight.

Push the membrane housing back down into the mounting brackets.

Remove the white product tubing that runs from the RO membrane to the ion-exchange cartridge, at the ion-exchange cartridge by pushing in the ring around the tubing and pulling on the tubing.

Turn on the tap and run the system for 1 hour with the RO product water going to waste.

Replace the white product tubing in the ion-exchange cartridge housing and the system is now ready for use.

6. Troubleshooting

Problem	Possible cause	Corrective action
Product water > 1µs/cm	Ion-exchange cartridge exhausted.	Replace cartridge.
	Water tested has been standing for some time and absorbed CO_2 from the air.	Measure with fresh sample or preferably running water.
Low RO membrane salt rejection	Low system feed pressure	The system requires a minimum of 35 psi and ideally about 60 psi to operate effectively. Contact Ibis Technology or your distributor for information on booster pumps
	Prefilter blocked check pressure reading on gauge.	If pressure reading low change prefilter.
	RO membrane fouled	Service or replace RO membrane.
	Product and waste flows out of specification	Contact Ibis Technology or your distributor
Low product flow rate.	Prefilter blocked check pressure reading on gauge.	If pressure reading low change prefilter.
	RO membrane fouled.	Service or replace RO membrane.
Ion-exchange cartridge life shorter than previous.	Water usage increased.	
	Seasonal or other variations in feed water quality.	In some areas the quality of tap water can vary by 50% over the year.
	RO membrane salt rejection reduced.	Check membrane salt rejection and either replace or service membrane.
System does not shut off when tank is full.	Float valve faulty.	Check water is not leaking past float valve when tank is full. If this occurs replace float valve.
	Shut-off valve failure.	Replace RO membrane housing.
	Water pressure fluctuating or low	Contact Ibis Technology or your distributor.
Leak from housing after changing cartridge.	Housing O-ring not sealing.	Check O-ring is in place and coat with a small layer of Vaseline. If housing still leaks replace O-ring.
Leaks from system fittings	Tubing not seated fully in fitting.	Push tubing fully into fitting.
		Replace tubing and or fitting

7. Warranty

Thank you for purchasing an Ibis Technology product. We at Ibis Technology take pride in our customer service and will always strive to our best for you, the customer. However it is necessary to set out in writing some of our mutual rights and obligations.

Ibis Technology (The "Company") warrants its products for 12 months for defects in materials and workmanship when those products are used in accordance with their instructions. This warranty does not apply to filters or reverse osmosis membranes, which are referred to separately below.

The company's entire obligation shall be to repair or replace at the company's option any product or part of a product that has been found by the company to be defective.

Ibis Technology makes no other warranty either express or implied and will not be liable for consequential damages resulting from economic loss or property damage from the use of the company's products.

This warranty shall not restrict or modify the statutory rights of the purchaser.

This warranty shall be void if any modifications or repairs are made to the company's product by any person not authorised by the company to make such repairs or alterations.

Filters
There is no warranty possible on filters due to the unpredictable nature of water supplies. While all care is taken by the company to ensure the correct filters are supplied and filter life predictions are accurate, seasonal, regional and other fluctuations in the water supply make it impossible to warranty prefilters and post-filters.

Reverse Osmosis Membranes
Any warranty on reverse osmosis (RO) membranes will be limited to a pro-rata basis based on the 12 month warranty period. RO membrane warranty may be void if the following conditions are not adhered to.
Prefilters must be changed as specified by the company either in the manual or in person or by other correspondence.
Records of system performance and prefilter changes must be kept in writing.
Ibis Technology must be consulted before moving a system to a new location.
If chlorine levels in the feed water increase or throughput from the system increases please consult Ibis Technology immediately. (Chlorine monitoring kits are available from Ibis Technology)

Ibis Technology
e-mail csibis@space.net.au
PO Box 104 Mount Hawthorn WA 6915
Phone (08) 9443 9121 Fax (08) 9443 9115

1.4 **Specification of** the NI PCI- 6025E Data Acquisition (DAQ) card[3]

Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

NI E Series – Low-Cost

- 16 analog inputs at up to 200 kS/s, 12 or 16-bit resolution
- Up to 2 analog outputs at 10 kS/s, 12 or 16-bit resolution
- 8 digital I/O lines (TTL/CMOS); two 24-bit counter/timers
- Digital triggering
- 4 analog input signal ranges
- NI-DAQ driver that simplifies configuration and measurements

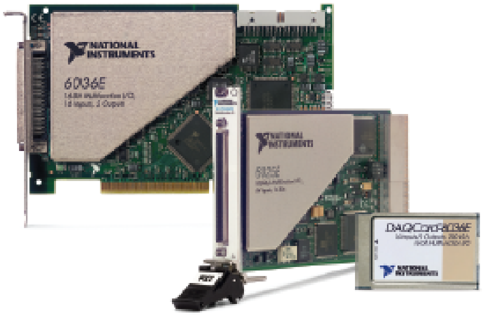
Families
- NI 6036E
- NI 6034E
- NI 6025E
- NI 6024E
- NI 6023E

Operating Systems
- Windows 2000/NT/XP
- Real-time performance with LabVIEW
- Others such as Linux® and Mac OS X

Recommended Software
- LabVIEW
- LabWindows/CVI
- Measurement Studio
- VI Logger

Other Compatible Software
- Visual Basic, C/C++, and C#

Driver Software (included)
- NI-DAQ 7



Family	Bus	Analog Inputs	Input Resolution	Max Sampling Rate	Input Range	Analog Outputs	Output Resolution	Output Rate	Output Range	Digital I/O	Counter/Timers	Triggers
NI 6036E	PCI, PCMCIA	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	2	16 bits	10 kS/s[1]	±10 V	8	2, 24-bit	Digital
NI 6034E	PCI	16 SE/8 DI	16 bits	200 kS/s	±0.05 to ±10 V	0	–	–	–	8	2, 24-bit	Digital
NI 6025E	PCI, PXI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s[1]	±10 V	8	2, 24-bit	Digital
NI 6024E	PCI, PCMCIA	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	2	12 bits	10 kS/s[1]	±10 V	8	2, 24-bit	Digital
NI 6023E	PCI	16 SE/8 DI	12 bits	200 kS/s	±0.05 to ±10 V	0	–	–	–	8	2, 24-bit	Digital

[1]10 kS/s typical when using the single DMA channel for analog output. 1 kS/s maximum when using the single DMA channel for either analog input or counter/timer operations. 1 kS/s maximum for PCMCIA DAQCard devices in all cases.

Table 1. Low-Cost E Series Model Guide

Overview and Applications

National Instruments low-cost E Series multifunction data acquisition devices provide full functionality at a price to meet the needs of the budget-conscious user. They are ideal for applications ranging from continuous high-speed data logging to control applications to high-voltage signal or sensor measurements when used with NI signal conditioning. Synchronize the operations of multiple devices using the RTSI bus or PXI trigger bus to easily integrate other hardware such as motion control and machine vision to create an entire measurement and control system.

Highly Accurate Hardware Design

NI low-cost E Series DAQ devices include the following features and technologies:

Temperature Drift Protection Circuitry – Designed with components that minimize the effect of temperature changes on measurements to less than 0.0010% of reading/°C.

Resolution-Improvement Technologies – Carefully designed noise floor maximizes the resolution.

Onboard Self-Calibration – Precise voltage reference included for calibration and measurement accuracy. Self-calibration is completely software controlled, with no potentiometers to adjust.

NI DAQ-STC – Timing and control ASIC designed to provide more flexibility, lower power consumption, and a higher immunity to noise and jitter than off-the-shelf counter/timer chips.

NI MITE – ASIC designed to optimize data transfer for multiple simultaneous operations using bus mastering with one DMA channel, interrupts, or programmed I/O.

NI PGIA – Measurement and instrument class amplifier that guarantees settling times at all gains. Typical commercial off-the-shelf amplifier components do not meet the settling time requirements for high-gain measurement applications.

PFI Lines – Eight programmable function input (PFI) lines that you can use for software-controlled routing of interboard and intraboard digital and timing signals.

RTSI or PXI Trigger Bus – Bus used to share timing and control signals between two or more PCI or PXI devices to synchronize operations.

RSE Mode – In addition to differential and nonreferenced single-ended modes, NI low-cost E Series devices offer the referenced single-ended (RSE) mode for use with floating-signal sources in applications with channel counts higher than eight.

Onboard Temperature Sensor – Included for monitoring the operating temperature of the device to ensure that it is operating within the specified range.

NATIONAL INSTRUMENTS

[3] Sources from : http://sine.ni.com/nips/cds/print/p/lang/en/nid/10971

Low-Cost E Series Multifunction DAQ – 12 or 16-Bit, 200 kS/s, 16 Analog Inputs

		Full-Featured E Series				Low-Cost E Series		Basic
Models		NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6036E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014
Measurement Sensitivity[1] (mV)		0.0023	0.0025	0.009	0.008	0.0036	0.008	0.004
Nominal Range (V)								
Positive FS	**Negative FS**	**Absolute Accuracy (mV)**						
10	-10	1.147	4.747	14.369	15.373	7.560	16.504	8.984
5	-5	2.077	0.876	5.193	5.697	1.790	5.263	2.003
2.5	-2.5	–	1.190	3.605	3.859	–	–	–
2	-2	0.836	–	–	–	–	–	–
1	-1	0.422	0.479	1.452	1.556	–	–	–
0.5	-0.5	0.215	0.243	0.735	0.789	0.399	0.846	0.471
0.25	-0.25	–	0.137	0.379	0.405	–	–	–
0.2	-0.2	0.102	–	–	–	–	–	–
0.1	-0.1	0.061	0.064	0.163	0.176	–	–	–
0.05	-0.05	–	0.035	0.091	0.100	0.0611	0.106	0.069
10	0	0.976	1.232	6.765	7.269	–	–	–
5	0	1.992	2.119	5.391	5.645	–	–	–
2	0	0.802	0.850	2.167	2.271	–	–	–
1	0	0.405	0.428	1.092	1.146	–	–	–
0.5	0	0.207	0.242	0.558	0.583	–	–	–
0.2	0	0.098	0.111	0.235	0.247	–	–	–
0.1	0	0.059	0.059	0.127	0.135	–	–	–

Note: Accuracies are valid for measurements following an internal calibration. Measurement accuracies are listed for operational temperatures within ±1 °C of internal calibration temperature and ±10 °C of external or factory-calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ±10 V range) after one year, assuming 100 pt averaging of data.

[1]Smallest detectable voltage change in the input signal at the smallest input range.

Table 2. E Series Analog Input Absolute Accuracy Specifications

		Full-Featured E Series				Low-Cost E Series		Basic
Models		NI 6030E, NI 6031E, NI 6032E, NI 6033E	NI 6052E	NI 6070E, NI 6071E	NI 6040E	NI 6034E, NI 6036E	NI 6023E, NI 6024E, NI 6025E	PCI-6013, PCI-6014
Nominal Range (V)								
Positive FS	**Negative FS**	**Absolute Accuracy (mV)**						
10	-10	1.430	1.405	8.127	8.127	2.417	8.127	3.835
10	0	1.201	1.176	5.685	5.685	–	–	–

Table 3. E Series Analog Output Absolute Accuracy Specifications

High-Performance, Easy-to-Use Driver Software

NI-DAQ is the robust driver software that makes it easy to access the functionality of your data acquisition hardware, whether you are a beginning or advanced user. Helpful features include:

Automatic Code Generation – DAQ Assistant is an interactive guide that steps you through configuring, testing, and programming measurement tasks and generates the necessary code automatically for NI LabVIEW, LabWindows/CVI, or Measurement Studio.

Cleaner Code Development – Basic and advanced software functions have been combined into one easy-to-use yet powerful set to help you build cleaner code and move from basic to advanced applications without replacing functions.

High-Performance Driver Engine – Software-timed single-point input (typically used in control loops) with NI-DAQ achieves rates of up to 50 kHz. NI-DAQ also delivers maximum I/O system throughput with a multithreaded driver.

Test Panels – With NI-DAQ, you can test all of your device functionality before you begin development.

Scaled Channels – Easily scale your voltage data into the proper engineering units using the NI-DAQ Measurement Ready virtual channels by choosing from a list of common sensors and signals or creating your own custom scale.

LabVIEW Integration – All NI-DAQ functions create the waveform data type, which carries acquired data and timing information directly into more than 400 LabVIEW built-in analysis routines for display of results in engineering units on a graph.

***For information on applicable hardware for NI-DAQ 7, visit* ni.com/dataacquisition.**

Visit* ni.com/oem *for quantity discount information.

Recommended Accessories

Signal conditioning is required for sensor measurements or voltage inputs greater than 10 V. National Instruments SCXI is a versatile, high-performance signal conditioning platform, intended for high-channel-count applications. NI SCC products provide portable, flexible signal conditioning options on a per-channel basis. Both signal conditioning platforms are designed to increase the performance and reliability of your DAQ system, and are up to 10 times more accurate than terminal blocks (please visit **ni.com/sigcon** for more details). Refer to the table below for more information:

Sensor/Signals (>10 V)

System Description	DAQ Device	Signal Conditioning
High-performance	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCXI
Low-cost, portable	PCI-60xxE, PXI-60xxE, DAQCard-60xxE	SCC

Signals (<10 V)[1]

System Description	DAQ Device	Terminal Block	Cable
Shielded	PCI-60xxE	SCB-68	SH6868-EP
Shielded	PXI-60xxE	TB-2705	SH6868-EP
Shielded	DAQCard-60xxE	SCB-68	SHC6868-EP
Low-cost	PCI-6025E/PXI-6025E	Two TBX-68s	SH1006868
Low-cost	PCI-60xxE/PXI-60xxE	CB-68LP	R6868
Low-cost	DAQCard-60xxE	CB-68LP	RC686B

[1]Terminal blocks do not provide signal conditioning (i.e., filtering, amplification, isolation, and so on), which may be necessary to increase the accuracy of your measurements.

Table 4. Recommended Accessories

1.6 Dedicated MATLAB codes for predictive models of electrolyser

```
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%
%==========================================================================
%
%            Mr. Tien Ho Nhut, 040030
%      Supervisor: A/Prof. Vishy Karri
%==========================================================================
% ==================
% Filename: start.m
% ==================

clc;

K = MENU('Hydrogen Predictive Models using Intelligent Technologies','-------- Back↙
Propagation Neural Network--------','----Adaptive Neuro-Fuzzy Inference↙
System-----','-----------Close the Window!------------');

if K == 1
    Run option
elseif K==2
    Run ANFISoption
else K == 3
    button = questdlg('Ready to quit?', 'Exit Dialog','Yes','No','No');

    switch button
    case 'Yes',
        disp('Exiting MATLAB');
        %Save variables to matlab.mat

        close all
    case 'No',
        quit cancel;
        run start;
    end
end
```

```
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%==========================================================================
%
%            Mr. Tien Ho Nhut, 040030
%      Supervisor: A/Prof. Vishy Karri
%==========================================================================
%

clc;

K = MENU('PLEASE CHOOSE SPECIFIC ALGORITHM TO TRAIN THE NETWORK','Levenberg-Marquardt
backpropagation trainlm','Gradient descent backpropagation traingd', 'Gradient↙
descent with momentum backpropagation traingdm','Gradient descent with adaptive↙
learning rate backpropagation traingda','Gradient descent with momentum and adaptive
learning rate backpropagation traingdx','Resilient backpropagation','Scaled conjugate
gradient backpropagation','Conjugate gradient backpropagation with Fletcher-Reeves↙
updates','Conjugate gradient backpropagation with Polak-Ribiere updates','Conjugate↙
gradient backpropagation with Powell-Beale restarts','One step secant↙
backpropagation','come back to start menu','Close the window!');

if K == 1
    Run lm
elseif K == 2
    Run d
elseif K == 3
    Run dm
elseif K == 4
    Run da
elseif K == 5
    Run dx
elseif K == 6
    Run rp
elseif K == 7
    Run sc
elseif K == 8
    Run cgf
elseif K == 9
    Run cgp
elseif K == 10
    Run cgb
elseif K == 11
    Run oss
elseif K == 12
    Run start
else K == 13
    button = questdlg('Ready to quit?', 'Exit Dialog','Yes','No','No');

    switch button
    case 'Yes',
        disp('Exiting MATLAB');
        %Save variables to matlab.mat
        close all

    case 'No',
        quit cancel;
```

```
        RUN option;
    end
end


clc;
clear;
clear all
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%===========================================================================
%
%           Mr. Tien Ho Nhut, 040030
%     Supervisor: A/Prof. Vishy Karri
%===========================================================================
%
% ==================
% Filename: ANFISoption
% ==================

clc;

K = MENU('Please choose output target','% Lower explosive limit', 'Product hydrogen
pressure','Product hydrogen flow rate','Close the window!');

if K == 1
    Run tienfinal_LeL
elseif K == 2
    Run tienfinal_HP
elseif K == 3
    Run tienfinal_HF

else K == 4
    button = questdlg('Ready to quit?', 'Exit Dialog','Yes','No','No');

    switch button
    case 'Yes',
        disp('Exiting MATLAB');
        %Save variables to matlab.mat
        close all
    case 'No',
        quit cancel;
    end
end
```

```
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%===========================================================================
%
%            Mr. Tien Ho Nhut, 040030
%      Supervisor: A/Prof. Vishy Karri
%===========================================================================
%
% ==================
% Filename: lm.m
% ==================

clc;

K = MENU('PLEASE CHOOSE OUTPUT TARGET','% Lower explosive limit', 'Product hydrogen↙
pressure','Product hydrogen flow rate','Close the window!');

if K == 1
    Run gasdetectlm
elseif K == 2
    Run productpressurelm
elseif K == 3
    Run hydrogenflowlm

else K == 4
    button = questdlg('Ready to quit?', 'Exit Dialog','Yes','No','No');

    switch button
    case 'Yes',
        disp('Exiting MATLAB');
        %Save variables to matlab.mat
        close all
    case 'No',
        quit cancel;
        RUN lm;
    end
end
```

```
close all
echo on;
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%==========================================================================
%
%            Mr. Tien Ho, 040030
% File name: gasdetectlm.m
%==========================================================================
%


clc;
clear;
clear all
load 'hogen1.m';

rand('state',sum(100*clock));

Num1 = randperm(760);

Train = [];

Test = [];
for i = 1:760
    Train = [Train; hogen1((Num1(i)),:)];
end
for i = 701:760
    Test = [Test; hogen1((Num1(i)),:)];
    tp = [min(Train(:,11)), max(Train(:,11))];
end


% ============================================================
% Back-propagation algorithm:
% ============================================================

% ============================================================
% Problem: The three-layer back-propagation network is required
% ============================================================
pause(1)

echo off
p1 = [min(Train(:,1)), max(Train(:,1))];
p2 = [min(Train(:,2)), max(Train(:,2))];
p3 = [min(Train(:,3)), max(Train(:,3))];
p4 = [min(Train(:,4)), max(Train(:,4))];
p5 = [min(Train(:,5)), max(Train(:,5))];
p6 = [min(Train(:,6)), max(Train(:,6))];
p7 = [min(Train(:,7)), max(Train(:,7))];
p8 = [min(Train(:,8)), max(Train(:,8))];
p9 = [min(Train(:,9)), max(Train(:,9))];
p10 = [min(Train(:,10)), max(Train(:,10))];

t1 = [min(Train(:,11)), max(Train(:,11))];
t2 = [min(Train(:,12)), max(Train(:,12))];
```

```
t3 = [min(Train(:,13)), max(Train(:,13))];

% define now the network architecture and create the network and initialise
% its weights and biases.

s1=8; %10 neurons in the hidden layer
s2=1; %1 neurons in the output layer


net = newff([p1; p2; p3; p4; p5; p6; p7; p8; p9; p10],[s1,s2],{'tansig','purelin',↙
},'trainlm');

% Hit any key to set up the frequency of the training progress to be displayed,
% maximum number of epochs, acceptable error, learning rate, and momentum
% constant

net.trainParam.show = 100;      % Number of epochs between showing the progress
net.trainParam.epochs = 2000; % Maximum number of epochs
net.trainParam.goal = 0.001;  % Performance goal
net.trainParam.lr = 0.01;     % Learning rate
net.trainParam.lr_inc = 1.05; % Learning rate increase multiplier
net.trainParam.lr_dec = 0.7;  % Learning rate decrease multiplier
net.trainParam.mc = 0.95;     % Momentum constant

% Now train the back-propagation network

p = Train(:,1:10);
p=p';
t = Train(:,11);
t = t';
net = train(net,p,t);
ti = clock;
Y = sim(net,p);
time=etime(clock,ti);
disp(time);
Y1 = Y';
t1 = t';
p1 = p';
t1 = t1.*(48-27) + 27;
p1 = p1'.*(48-27) + 27;
Y1 = Y1.*(48-27) + 27;
figure(1)
plot(t,'-b','LineWidth',2)
legend('Actual',0);
title('Training Gas detect');

xlabel('Number of Training data');
ylabel('% Lower explosive limit');
hold on
plot(Y,'-.r','LineWidth',0.5)
legend('Training',1);
error = t1 - Y1;
disp([t1, Y1, error]);

disp('Here is a plot of the error occurances');
```

```
figure(2);
plot((error))
title('Training Error for % Lower explosive limit');
xlabel('Number of Training data');
ylabel('% Lower explosive limit');
disp('RMS % deviation');
q1=(-error./Y1)*100;
q2=q1.^2;
q3 = sum(q2);
q4=sqrt(q3);
q5=q4/700;
disp(q5)

disp(' %ARMS error');
w1=error.^2;
w2=sum(w1);
w3=w2/700;
w4=(w3)^(0.5);
w5 = mean(Y1);
w6 = (w4/w5)*100;
disp(w6)


figure(3);
x = -9.9:0.5:9.9;
hist(error,x)
h = findobj(gca,'Type','patch');
set(h,'FaceColor','b','EdgeColor','w')
title('Training histogram');
xlabel('Error (actual - predicted values)');
ylabel('Frequency');


p1 = [Test(:,1:10)]';
OUT = [Test(:,11)];
a = sim(net,p1);
b=a';
out1 = OUT.*(48-27) + 27;
a1 = a'.*(48-27) + 27;

figure(4)
plot(out1,'-b','LineWidth',2)
title('Comparison of Actual and Network Predicted Values for % LEL');
xlabel('Number of Testing data');
ylabel('% Lower explosive limit');
legend('Actual',0);
hold on
plot(a1,'-.r', 'Linewidth',1.5)


error1 = out1 - a1;

disp('Here is the expected output data');
disp('And the data that the computer has calculated');
```

```
disp('Hit ENTER to continue');


disp('    (actual output) (predict output)   (Error Data)');
disp([out1, a1, error1])
disp('Here is a plot of the error occurances');

figure(5);
plot((error1))
title('Prediction error for % Lower explosive limit');
xlabel('Number of Testing data');
ylabel('% Lower explosive limit');
disp('RMS % deviation');
k1=(-error1./a1)*100;
k2=q1.^2;
k3 = sum(q2);
k4=sqrt(q3);
k5=q4/60;
disp(k5)


disp('Avergae %RMS error');
g1=error1.^2;
g2=sum(g1);
g3=g2/60;
g4=(g3)^(0.5);
g5 = mean(a1);
g6 = (g4/g5)*100;
disp(g6)


figure(7);
x = -9.9:0.5:9.9;
hist(error1,x)
h = findobj(gca,'Type','patch');
set(h,'FaceColor','b','EdgeColor','w')
title('Testing histogram');
xlabel('Error (actual - predicted values)');
ylabel('Frequency');

%clc;
%clear;
```

```
function varargout = modaldlg(varargin)
% MODALDLG Application M-file for untitled.fig
%    MODALDLG, by itself, creates a new MODALDLG or raises the existing
%    singleton*.
%
%    H = MODALDLG returns the handle to a new MODALDLG or the handle to
%    the existing singleton*.
%
%    MODALDLG('CALLBACK',hObject,eventData,handles,...) calls the local
%    function named CALLBACK in MODALDLG.M with the given input argumen
%
%    MODALDLG('Property','Value',...) creates a new MODALDLG or raises
%    existing singleton*.  Starting from the left, property value pairs
%    applied to the GUI before modaldlg_OpeningFunction gets called.  A
%    unrecognized property name or invalid value makes property applica
%    stop.  All inputs are passed to modaldlg_OpeningFcn via varargin.
%
%    *See GUI Options - GUI allows only one instance to run (singleton)
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',          mfilename, ...
                   'gui_Singleton',     gui_Singleton, ...
                   'gui_OpeningFcn',    @modaldlg_OpeningFcn, ...
                   'gui_OutputFcn',     @modaldlg_OutputFcn, ...
                   'gui_LayoutFcn',     [], ...
                   'gui_Callback',      []);
if nargin & isstr(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    varargout{1:nargout} = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before modaldlg is made visible.
function modaldlg_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to modaldlg (see VARARGIN)

% Choose default command line output for modaldlg
handles.output = 'Yes';

% Update handles structure
guidata(hObject, handles);
```

```
% Insert custom Title and Text if specified by the user
if(nargin > 3)
    for index = 1:2:(nargin-3),
        switch lower(varargin{index})
        case 'title'
            set(hObject, 'Name', varargin{index+1});
        case 'string'
            set(handles.string, 'String', varargin{index+1});
        otherwise
            error('Invalid input arguments');
        end
    end
end

% Determine the position of the dialog - centered on the callback figure
% if available, else, centered on the screen
FigPos=get(0,'DefaultFigurePosition');
FigWidth=215;FigHeight=88;
if isempty(gcbf)
    ScreenUnits=get(0,'Units');
    set(0,'Units','points');
    ScreenSize=get(0,'ScreenSize');
    set(0,'Units',ScreenUnits);

    FigPos(1)=1/2*(ScreenSize(3)-FigWidth);
    FigPos(2)=2/3*(ScreenSize(4)-FigHeight);
else
    GCBFOldUnits = get(gcbf,'Units');
    set(gcbf,'Units','points');
    GCBFPos = get(gcbf,'Position');
    set(gcbf,'Units',GCBFOldUnits);
    FigPos(1:2) = [(GCBFPos(1) + GCBFPos(3) / 2) - FigWidth / 2, ...
                   (GCBFPos(2) + GCBFPos(4) / 2) - FigHeight / 2];
end
FigPos(3:4)=[FigWidth FigHeight];
set(hObject, 'position', FigPos);

% Show a question icon from dialogicons.mat - variables questIconData
% and questIconMap
load dialogicons.mat
%
IconData=questIconData;
questIconMap(256,:)=get(handles.figure1, 'color');
IconCMap=questIconMap;

axes(handles.axes1);
Img=image(IconData);
set(handles.figure1, 'Colormap', IconCMap);

set(gca, ...
    'Visible', 'off', ...
    'YDir'   ,'reverse'       , ...
    'XLim'   ,get(Img,'XData'), ...
    'YLim'   ,get(Img,'YData')  ...
    );
```

```
% UIWAIT makes modaldlg wait for user response (see UIRESUME)
uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.
function varargout = modaldlg_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

% The figure can be deleted now
delete(handles.figure1);

% --- Executes on button press in yes_button.
function yes_button_Callback(hObject, eventdata, handles)
% hObject    handle to yes_button (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

handles.output = get(hObject,'String');

% Update handles structure
guidata(hObject, handles);

% Use UIRESUME instead of delete because the OutputFcn needs
% to get the updated handles structure.
uiresume(handles.figure1);

% --- Executes on button press in no_button.
function no_button_Callback(hObject, eventdata, handles)
% hObject    handle to no_button (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

handles.output = get(hObject,'String');

% Update handles structure
guidata(hObject, handles);

% Use UIRESUME instead of delete because the OutputFcn needs
% to get the updated handles structure.
uiresume(handles.figure1);


% --- Executes when user attempts to close figure1.
function figure1_CloseRequestFcn(hObject, eventdata, handles)
% hObject    handle to figure1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

if isequal(get(handles.figure1, 'waitstatus'), 'waiting')
```

```
    % The GUI is still in UIWAIT, us UIRESUME
    uiresume(handles.figure1);
else
    % The GUI is no longer waiting, just close it
    delete(handles.figure1);
end


% --- Executes on key press over figure1 with no controls selected.
function figure1_KeyPressFcn(hObject, eventdata, handles)
% hObject    handle to figure1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Check for "enter" - do uiresume if we get it
if isequal(get(hObject,'CurrentKey'),'return')
    uiresume(handles.figure1);
end
```

```
% PROGRAM WRITTEN, EDITED COMPLIED AND TESTED BY:
%
%==========================================================================
%
%           Mr.Tien HO, 040030
% File name: Tienfinal_LeL.m   ( using ANFIS to predict LeL)
%==========================================================================
%
function varargout = tienfinal_LeL(varargin)
% TIENFINAL_LEL M-file for tienfinal_LeL.fig
%      TIENFINAL_LEL, by itself, creates a new TIENFINAL_LEL or raises the existing
%      singleton*.
%
%      H = TIENFINAL_LEL returns the handle to a new TIENFINAL_LEL or the handle to
%      the existing singleton*.
%
%      TIENFINAL_LEL('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in TIENFINAL_LEL.M with the given input arguments.
%
%      TIENFINAL_LEL('Property','Value',...) creates a new TIENFINAL_LEL or raises ↙
the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before tienfinal_LeL_OpeningFunction gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to tienfinal_LeL_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Copyright 2002-2003 The MathWorks, Inc.

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @tienfinal_LeL_OpeningFcn, ...
                   'gui_OutputFcn',  @tienfinal_LeL_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before tienfinal_LeL is made visible.
```

```
function tienfinal_LeL_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to tienfinal_LeL (see VARARGIN)
global RGB
% Choose default command line output for tienfinal_LeL
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

RGB = imread('hydro.jpg');                              % load the image
imshow(RGB)
hold on

clc
clear
% UIWAIT makes tienfinal_LeL wait for user response (see UIRESUME)
% uiwait(handles.figure1);


% --- Outputs from this function are returned to the command line.
function varargout = tienfinal_LeL_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;



function mf_Callback(hObject, eventdata, handles)
% hObject    handle to mf (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of mf as text
%        str2double(get(hObject,'String')) returns contents of mf as a double
global mf_in

mf_in = str2double(get(hObject,'string'))

if isnan(mf_in)
    errordlg('You must enter a numeric value between 1 and 10','Bad Input','modal')
end

if mf_in > 10
    errordlg('we recommend membership function value between 1 and 10','Bad↙
Input','modal')
end
```

```
if mf_in < 1
    errordlg('we recommend membership function value between 1 and 10','Bad↙
Input','modal')
end

% --- Executes during object creation, after setting all properties.
function mf_CreateFcn(hObject, eventdata, handles)
% hObject    handle to mf (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc
    set(hObject,'BackgroundColor','white');
else
    set(hObject,'BackgroundColor',get(0,'defaultUicontrolBackgroundColor'));
end



function edit2_Callback(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as text
%        str2double(get(hObject,'String')) returns contents of edit2 as a double

global epoch_in

epoch_in = str2double(get(hObject,'string'))

if isnan(epoch_in)
    errordlg('You must enter a numeric value between 10 and 100','Bad Input','modal')
end

if epoch_in > 10
    errordlg('we recommend number of training epoch value between 10 and 100','Bad↙
Input','modal')
end

if epoch_in < 1
    errordlg('we recommend number of training epoch value between 10 and 100','Bad↙
Input','modal')
end
% --- Executes during object creation, after setting all properties.
function edit2_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc
```

```
    set(hObject,'BackgroundColor','white');
else
    set(hObject,'BackgroundColor',get(0,'defaultUicontrolBackgroundColor'));
end


% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
open help.doc

% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global mf_in epoch_in
numMFs = 2;          % Number of membership functions assigned to an input variable
mfType = 'gbellmf'; % Type of the membership function
epoch_n = 10;       % Number of training epochs

[a b c d e f g h i j]= ANFIS_data1();



% x = [a;b;c;d;e;f;g;h;i;j];
for i=1:5
    if i==1
x = [a];
    elseif i==2
        x=[b]
    elseif i==3
        x=[c]
    elseif i==4
        x=[d]
        else i==5
        x=[e]
    end


for t=4:120,
Data(t-3,:)=[x(t-3) x(t-2) x(t-1) x(t) x(t+1)];
end
trnData=Data(1:end,:);

for t=4:119,
Data(t-3,:)=[x(t-3) x(t-2) x(t-1) x(t) x(t+1)];
end
chkData=Data(1:end, :);
y=[];
global y
z = [x;y];
```

```
fismat = genfis1(trnData,numMFs,mfType);

[fismat1,error1,ss,fismat2,error2] = ...
   anfis(trnData,fismat,[],[],chkData);


end
figure(2)
subplot(2,2,1)
plotmf(fismat, 'input', 1)
subplot(2,2,2)
plotmf(fismat, 'input', 2)
subplot(2,2,3)
plotmf(fismat, 'input', 3)
subplot(2,2,4)
plotmf(fismat, 'input', 4)

figure(3)
subplot(2,2,1)
plotmf(fismat2, 'input', 1)
subplot(2,2,2)
plotmf(fismat2, 'input', 2)
subplot(2,2,3)
plotmf(fismat2, 'input', 3)
subplot(2,2,4)
plotmf(fismat2, 'input', 4)

anfis_output = evalfis([trnData(:,1:4); chkData(:,1:4)], fismat2,epoch_n);

t = (0:0.5:60);
for index = 1:120
    hold on
    figure(4)
    title('On-line time series prediction of % Lower explosive Limit');
    xlabel('Time (second)');
    ylabel(' % Lower explosive Limit');

    if (index>4)
 plot(211), plot(t(index), anfis_output(index-4) , '--b.','LineWidth',1);
    pause(0.5)
    end
 plot(t(index), z(index) , '--rx','LineWidth',1);
hold on

figure (5)
title('On-line time series prediction error of % Lower explosive Limit');
    xlabel('Time (second)');
    ylabel(' % Lower explosive Limit');
 plot(t(index), z(index) - anfis_output(index),'--bx','LineWidth',1);
pause(0.002)
hold on
end
% --- Executes on button press in pushbutton3.
function pushbutton3_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton3 (see GCBO)
```

```
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

pos_size = get(handles.figure1,'Position');

% Call modaldlg with the argument 'Position'.
user_response = modaldlg('Title','Confirm Close');

switch user_response
    case {'No'}
        % take no action
    case 'Yes'
        % Prepare to close_pushbutton GUI application window
        close all
end
% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

mf_in = 0;
epoch_in =0;

pause(1)
clc;
clear all;
close all
Run tienfinal_LeL


% --- Executes on button press in pushbutton5.
function pushbutton5_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global y
y=[f];

% --- Executes on button press in pushbutton6.
function pushbutton6_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton6 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global y
y=[g];


% --- Executes on button press in pushbutton7.
function pushbutton7_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton7 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global y
y=[h];
```

```
% --- Executes on button press in pushbutton8.
function pushbutton8_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton8 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global y
y=[i];


% --- Executes on button press in pushbutton9.
function pushbutton9_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton9 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global y
y=[j];
```

1.7 User's guide for developed MATLAB ANNs and ANFIS

The program has been developed in this project by using many features of MATLAB package while still keeping the program as simple as possible. Thus it is possible to increase the usability of the program and decrease the complexity. A dedicated example of that is the "start.m" file that I have created. With this "start.m" file, it is simple for the user to type "start" into the command window, and then the user can use the mouse to select from the pop-up menu which option they wish to choose. Below is the screenshot of the "start" menu.

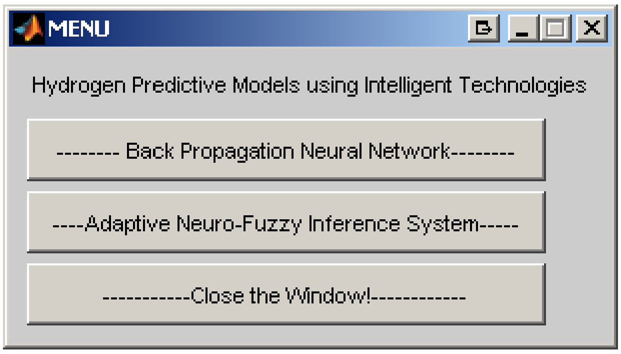


Figure: Start Menu for Program Developed

Basically, the user can chose the Back Propagation Neural Network (BPNN) or Adaptive Neural-Fuzzy Inference System (ANFIS) program they wish to run or they have the option of quitting the program. There is a simple "for loop" that looks at the input from the user so as to determine the option that they have chosen. Option 1 means the back propagation network program. Option 2 is the ANFIS program and option 3 is the close option.

If option 3 is chosen, then the value for K (local variable) is entered into a simple switch statement, where a second dialogue box is displayed asking the user for confirmation of the choice. If "no" is selected, the dialog box disappears and the user may choose a program, but if yes is chosen, all windows are closed and any presented variables will be saved in a file called "matlab.mat" and the program is terminated.

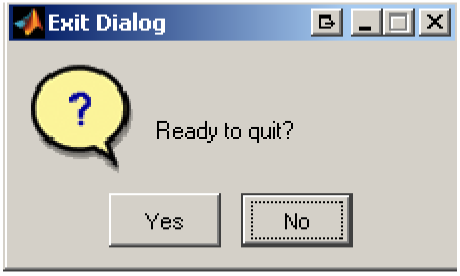


Figure: Exit Dialog Interface

If the user chooses the “Back Propagation Neural Network” button, the second interface BPNN menu with different algorithms is shown as below.

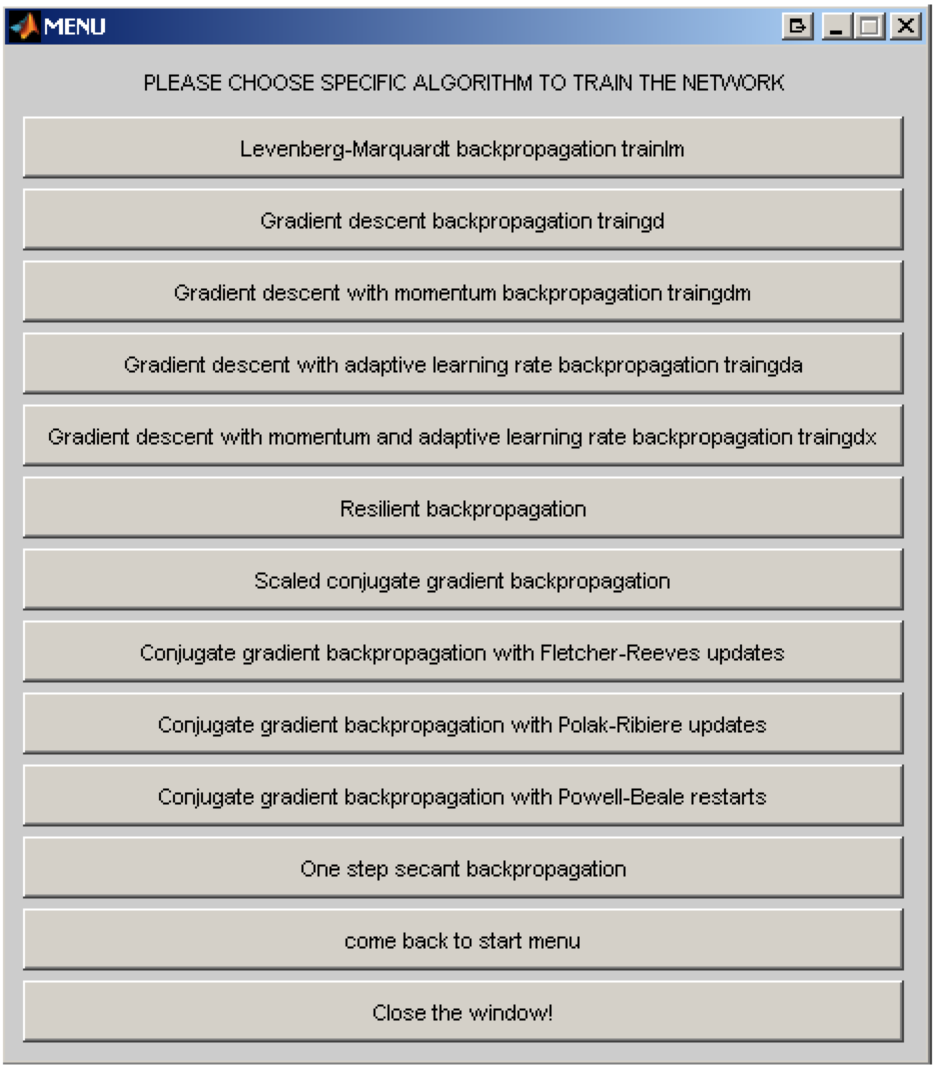


Figure: Back Propagation Neural Network menu.

Upon selecting one dedicated back propagation neural network algorithm (i.e the Levenberg-Marquardt back propagation by simply pressing the button “Levenberg-Marquardt back propagation "trainlm”), the program will then open another user interface which allows the user to choose which predictive parameter is to be trained and tested.

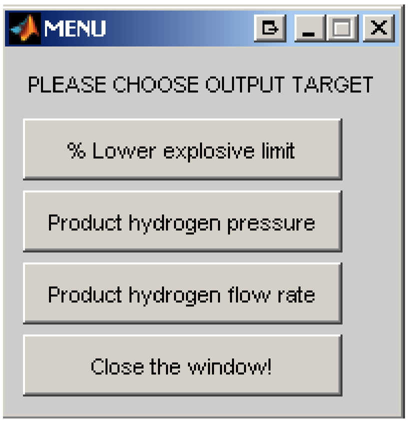


Figure: Selection of hydrogen predictive parameters.

Once a specific predictive parameter is chosen, the training process will occur and then all of the results with their performance graphs are also provided, (i.e. training error graph, training histogram, comparison of actual and network predicted values graph, prediction error graph, prediction error histogram as well as %ARMS and %RMS deviation.)

If the user choose ANFIS program in the start menu, the same selection of the hydrogen predictive parameters as shown in figure above is appeared. An example screenshot of choosing the prediction of %LeL explosive limit is shown below.

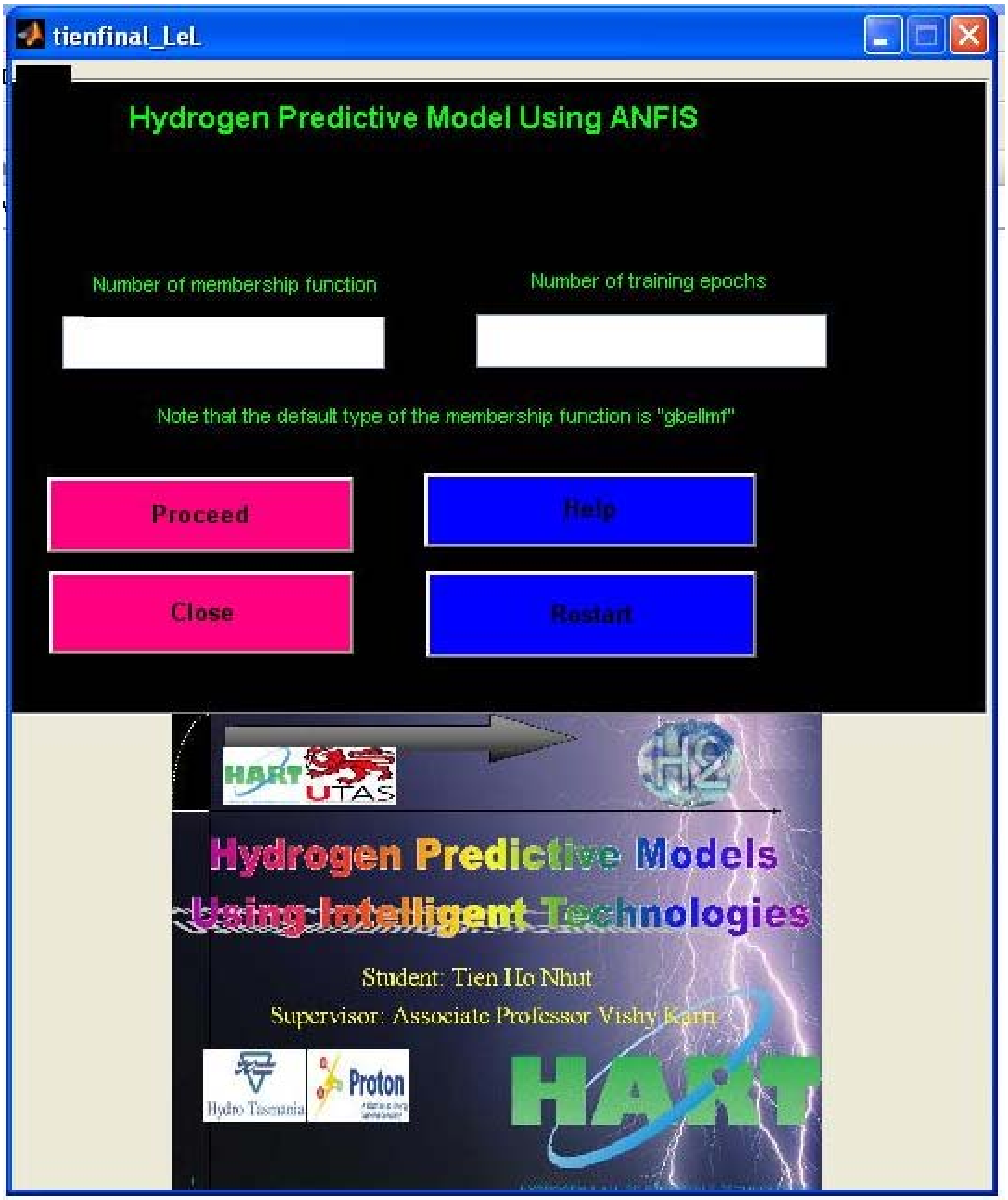


Figure: ANFIS prediction of %LeL

After entering appropriate number of member functions and number of epochs, the "proceed" button will allow the program to start the prediction task. The program also includes the following button:

- Help: a simple instruction on how to use this program will appear if presses this button.
- Restart: This button allows the user to restart the program.
- Close: This button to close the program and all associated windows.

1.8 Hydrogen Safety advisor

University Of Tasmania

HART program

Hydrogen safety instruction guide using Leonardo Expert System

Written By:

PhD candidate: Tien Ho Nhut, ID: 040030

Supervisor: Prof. Vishy Karri

1.8.1 Introduction

This small expert system covers some general issues regarding the (minimum) practices and safety measures applicable in the hydrogen laboratory in the school of Engineering (University of Tasmania). These measures are not intended for use outside this scope. Obviously, authorized laboratory users (those with keys to the facility) may experience some situations that are not covered in this expert system or the procedures in place. Under these circumstances or where in doubt, please refer back to Prof. Vishy Karri, Dr Yasir Al-Abdeli or Mr. Steven Avery.

"Hydrogen safety instruction guide" is the small expert system that studies the safety conditions upon the three actions that we can choose: [1]

Warning and error codes: **(errorcode)** the hydrogen generator (electrolyser) provides automatic shutdowns through continuous monitoring of critical operating parameters. If a parameter is not within its specified limits, the controller takes the appropriate action to the electrolyser generation process. Upon shut down the unit, the controller shows the error code for the type of shut down on 4-digit/7-segment display. Therefore, with this small expert system, the user just enter the error code and the program will show the description, default limit, sensor (P & ID Tag#), time activated, possible cause as well as suggestion to fix the error.

Percentage hydrogen in air conversion: **(conversion):** The combustible gas sensor which is used to detect the initiating gas generation for proper operation gas detecting within the laboratory safety equipment will show the percentage of lower flammable limit (LFL). The default of acceptable range of calibration gas is 30 percent to 50 percent LFL which is from 2% to 1.2% of hydrogen in air in laboratory show the safety operating environment as well as safe shut down of the system. With the use of this expert system, the user just enter the %LFL that are shown on 4-digit/7-segment display and the system will convert %LFL to % hydrogen in air , then give the conclusion whether we operate or working in the safety environment.

Calculate minimum ventilation requirement: (calculate ventilation requirement): The hydrogen laboratory is designed to operate in non-explosive internal operating environments. Base on the US patent 5980726 recommend an area air change rate of several hundred times the maximum generation rate of the electrolyser within the laboratory to preclude any possible build up of hydrogen concentration in the facility.

Therefore, refer to the local code requirements; we can determine the minimum facility ventilation requirements. The user just enter simple relevant data into the knowledge base and then the program will calculate the net hydrogen generation rate, gross hydrogen generation rate, recommended ventilation rate as well as the room exchange. After which, the conclusion about safety ventilation requirement will be given.

1.8.2 Domain Problem Description

The problems faced with some researcher and student who working in the hydrogen laboratory is the ability for them to accurately and quickly recognize error code, percentage hydrogen in air as well as calculate of ventilation requirement and have appropriate action at the right time without having to undertake a detailed analysis or instruction documentation which requires a large amount of time.

The ability for amateur authorized laboratory users to also have the opportunity to recognize these aspects within their own experiences is also hampered by the fact that complex calculation and time to fix the error without references suggestion.

A solution to this dilemma is to develop a system where the large majority of error code, percentage hydrogen in air as well as calculate of ventilation into one of the three major categories (error code, conversion and calculate_ventilation_requirement) and then further broken down to sub-categories in order to achieved the goal in question. The ability to provide this service to student and researcher alike would provide them with a valuable tool for hydrogen safety instruction guide and suggested action to fix error code.

By asking the right type of question to gain specific information, the problem can be identified quickly and easily using a Leonardo Expert System. The questions have been chosen and designed such that as much specific terminology information can be found out as possible, and this aids in quickly find out description of error code, percentage hydrogen in air conversion as well as calculate of ventilation requirements in question.

Using an expert system allows the researcher or student to assemble all their requirements into one easy database of knowledge, as well as having the option of refining, changing and adding rules to enlarge, or specify, the program.

The overall domain of this problem may be considered to be quite narrow, especially considering how wide the actual field is. The program that we have created here concentrates on the more “notable” aspects, i.e. problem and things that are most commonly need when consider safety hydrogen operating environment and suggested action to fix the error of electrolyser.

1.8.3 Expert System Overview

Leonardo is a complete expert system shell with all the tools necessary for us to design, develop, test and deliver expert systems with its own procedural programming language (PPL) which is modules of executable code. [2]

In a Leonardo knowledge base, we can:

Encoding algorithmic knowledge;

Performing complex arithmetic computations

Manipulating and design suitable screen for our purpose.

Linking to some of the external programs which are developed in C, FORTRAN, PASCAL, etc…

Accessing to the Graphics, Mathematics as well as Statistics field.

In the Leonardo complete expert system shell, structured programming language is describe from rules, from the compute value with slots, frame slots as well as many other procedure. With Leonardo expert system, procedures are recognised as objects and it will be set up automatically with the default frame, body as well as slots marks of the procedure body.

The following is the main parts of the Leonardo program:

The Knowledge Base. "This comprises the rules and objects which Leonardo uses to represent the expertise for a given application. As well as simple objects, the knowledge base stores objects with frames which hold additional information (such as screen design and procedures)".[2]

The Editor. "The Leonardo editor gives the facilities necessary to create and edit rules for the knowledge base and to edit information into object frames."[2]

Leonardo Procedural Programming Language. "Leonardo has its own Procedural Programming Language for constructing complex expert systems which may need to access external databases perform computations, and print complex reports, and so on." [2]

Check and Execute Functions. "Leonardo converts the raw knowledge base to a format which can be used by the computer." [2]

File Functions. "Leonardo provides facilities for maintaining the knowledge bases stored on the computer." [2]

1.8.4 Representation of the Knowledge Base

/* This program give the safety instruction guide, explain and /*suggest action to fix error code for those who working
/* in the hydrogen laboratory. For more information in regard to the
/* program, seek further documentation within the accompanying report.

seek target

use preamble_screen

use intro

ask action

Rule: 1

if action is conversion
then ask LFL

Rule: 2
if LFL > 0
then default = 0.04;
 convert = LFL * default;

Rule: 3
if convert > 2
then air is DANGER_ENVIRONMENT!

Rule: 4
if convert < 2
then air is SAFETY_ENVIRONMENT!

Rule: 5
if action is errorcode
then ask error

Rule: 6
if error is C00
then result is c0

Rule: 7
if error is C01
then result is c1

Rule: 8
if error is C02
then result is c2

Rule: 9
if error is C03
then result is c3

Rule: 10
if error is C04
then result is c4

Rule: 11
if error is C05
then result is c5

Rule: 12
if error is C06
then result is c6

Rule: 13
if error is C07

then result is c7

Rule: 14
if error is C08
then result is c8

Rule: 15

if error is C09
then resut is c9

Rule: 16
if error is C10
then result is c10

Rule: 17
if error is C11
then result is c11

Rule: 18
if error is C12
then result is c12

Rule: 19
if error is C30
then result is c30

Rule: 20
if error is E00
then result is e0

Rule: 21
if error is E01
then result is e1

Rule: 22
if error is E02
then result is e2

Rule: 23
if error is E03
then result is e3

Rule: 24
if error is E04
then result is e4

Rule: 25
if error is E05
then result is e5

Rule: 26
if error is E06
then result is e6

Rule: 27
if error is E07
then result is e7

Rule: 28
if error is E08
then result is e8

Rule: 29
if error is E09
then result is e9

Rule: 30
if error is E10
then result is e10

Rule: 31
if error is E11
then result is e11

Rule: 32
if error is E12
then result is e12

Rule: 33
if error is E13
then result is e13

Rule: 34
if error is E14
then result is e14

Rule: 35
if error is E15
then result is e15

Rule: 36
if error is E16
then result is e16

Rule: 37
if error is E17
then result is e17

Rule: 38

if error is E18
then result is e18

Rule: 39
if error is E19
then result is e19

Rule: 40
if error is E20
then result is e20

Rule: 41
if error is E21
then result is e21

Rule: 42
if error is E22
then result is e22

Rule: 43
if error is E23
then result is e23

Rule: 44
if error is E24
then result is e24

Rule: 45
if error is E25
then result is e25

Rule: 46
if error is E26
then result is e26

Rule: 47
if error is E27
then result is e27

Rule: 48
if error is E28
then result is e28

Rule: 49
if error is E29
then result is e29

Rule: 50
if error is E30
then result is e30

Rule: 51
if error is E31
then result is e31

Rule: 52
if error is E32
then result is e32

Rule: 53
if error is E33
then result is e33

Rule: 54
if error is E34
then result is e34

Rule: 55
if error is E35
then result is e35

Rule: 56
if error is E36
then result is e36

Rule: 57
if error is E37
then result is e37

Rule: 58
if error is E38
then result is e38

Rule: 59
if error is E39
then result is e39

Rule: 60
if error is E40
then result is e40

Rule: 61
if error is E41
then result is e41

Rule: 62
if action is calculate_ventilation_requirement
then ask choose_type

Rule: 63

```
if choose_type is Hogen20
then F = 2200;
     G = 22;
   ask Fa;
   ask volume

Rule: 64
if choose_type is Hogen40
then F = 4400;
     G = 44;
   ask Fa;
   ask volume


Rule: 65
if choose_type is Hogen60
then F = 6600;
     G = 66;
     ask Fa;
     ask volume

Rule: 66
if Fa < F
then conclusion is warning;
     R = Fa / volume

Rule: 67
if Fa > F
then R = Fa / volume

Rule: 68
if Fa < F
and R < 5
then conclusion is warning

Rule: 69
if Fa < F
and R > 5
then conclusion is warning

Rule: 70
if Fa > F
and R < 5
then conclusion is warning

Rule: 71
if Fa > F
and R > 5
then conclusion is safety
```

Rule: 72
if action is conversion
then target is air

Rule: 73
if action is errorcode
then target is result

Rule: 74
if action is calculate_ventilation_requirement
then target is conclusion

All objects are created in the program as below:

Object Name	**Object Type**
target	**text, real (number)**
preamble_screen	**text screen**
intro	**text screen**
action	**text**
LFL	**real (number)**
default	**integer (number)**
convert	**real (number)**
air	**real (number)**
error	**text**
result	**text**
choose type	**text**
F	**integer (number)**
G	**integer (number)**
Fa	**real (number)**
volume	**real (number)**
conclusion	**text**

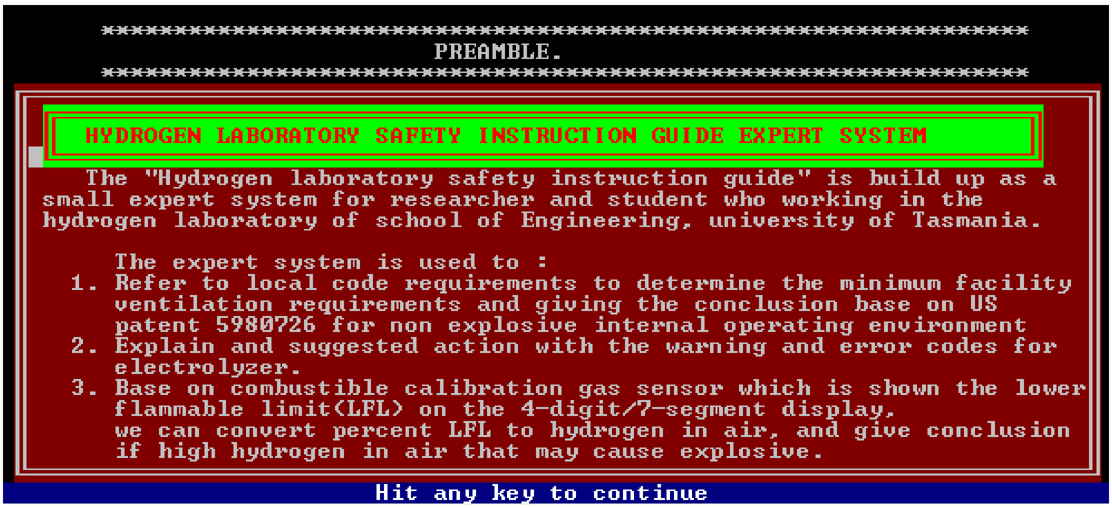
R	**real (number)**

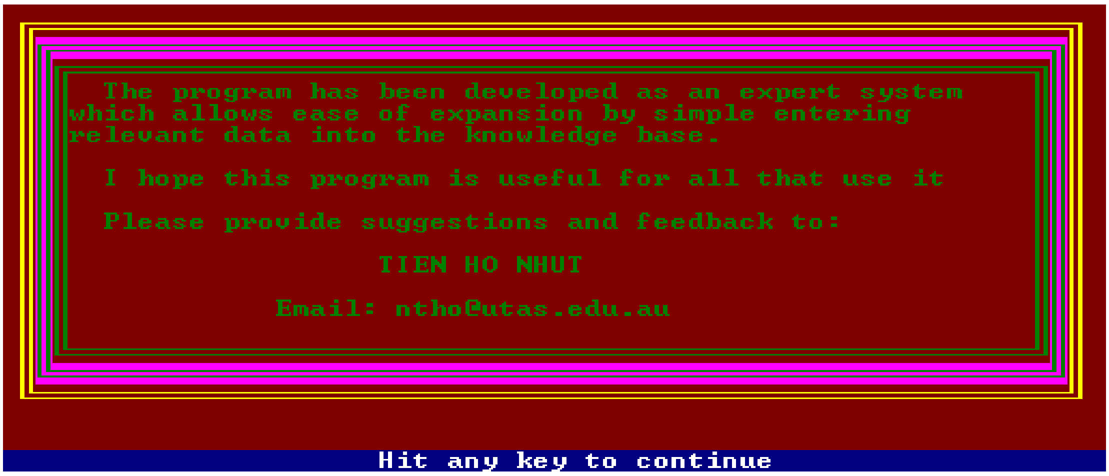
1.8.5 Description of the expert system application

Once a suitable problem of the expert system application was identified, research was undertaken to develop knowledge which was thought should to be included in the system. Initially the system was designed on paper by drawing up an application flow chart and drafting a few basic, simple rules.

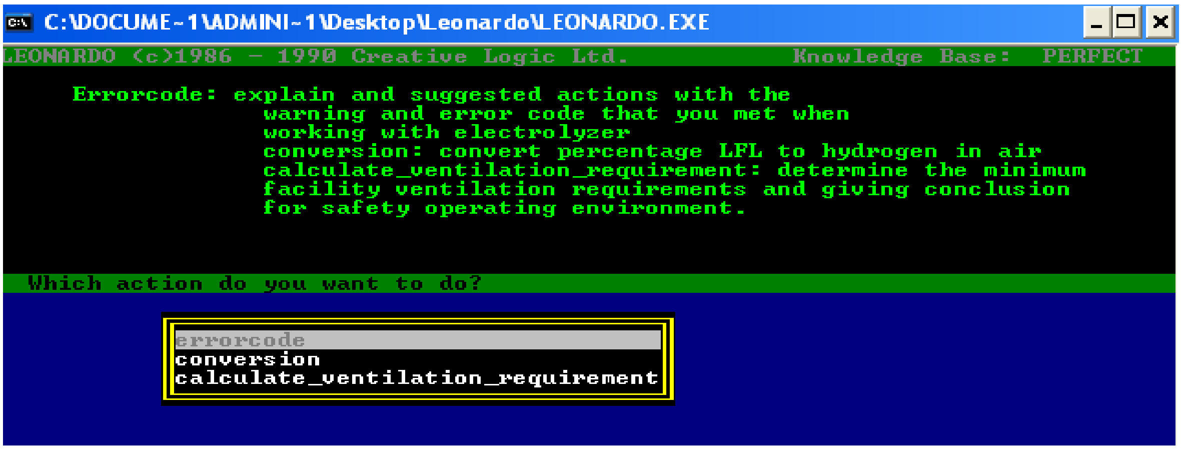
Now we will investigate the expert system application by simply try with one example test case for each action of the expert system.

The first introduction screen as below:

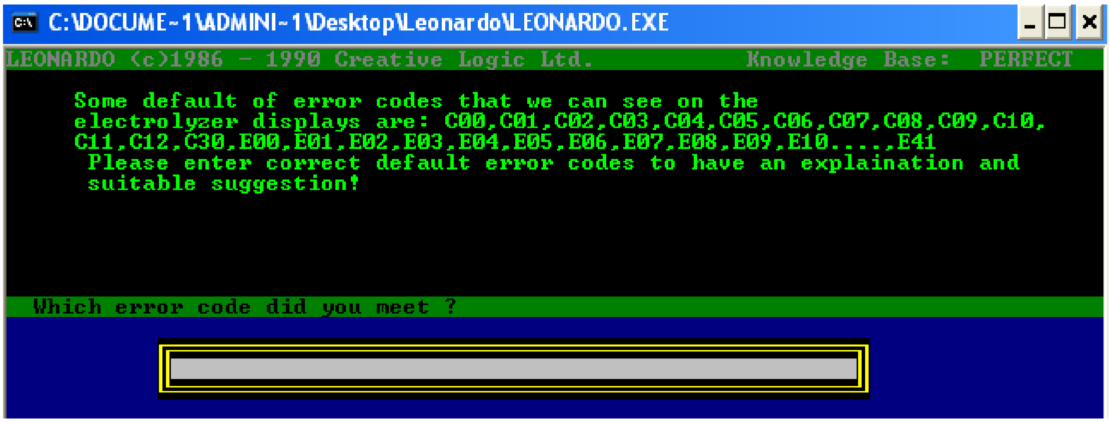




Then the program will prompt the user to choose: which action do you want to do?



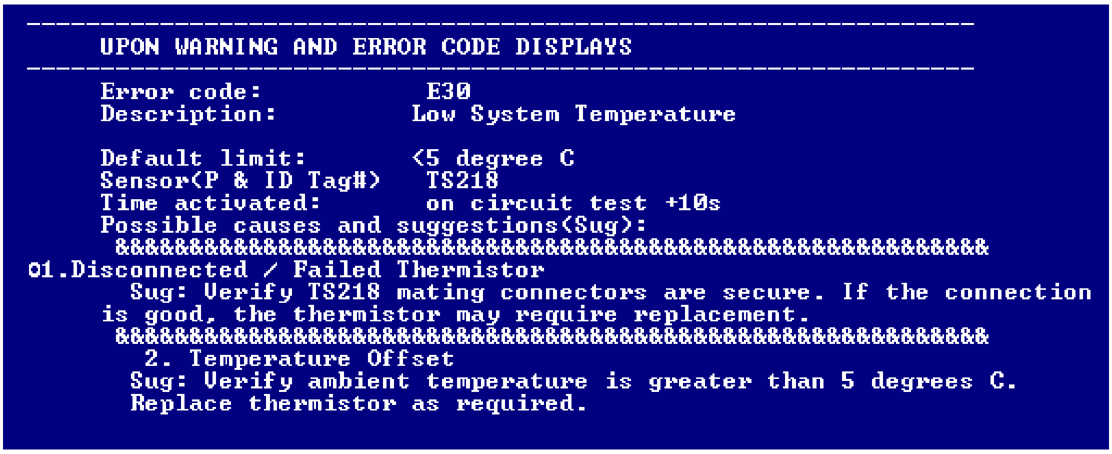
Firstly, I choose the action "errorcode", after that the screen will appear as below:



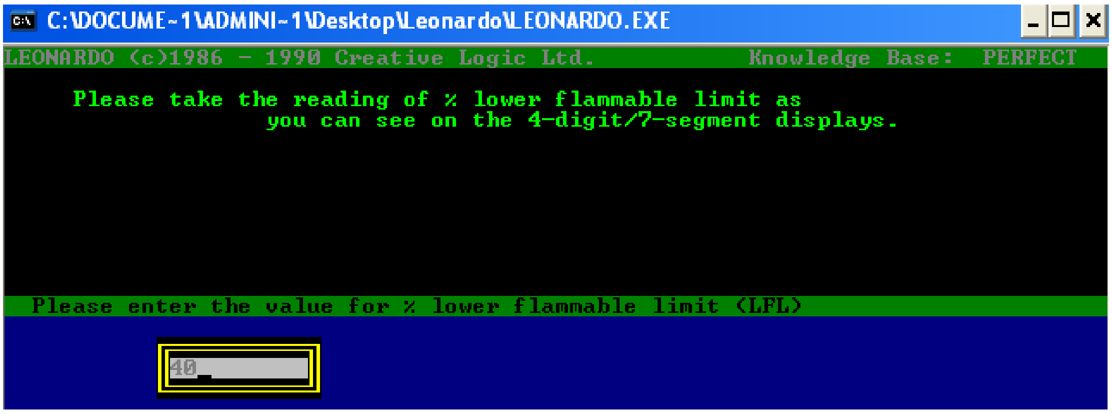
Some default of error code that we can see on the electrolyser displays are: C00, C01,C02,C03,C04,C05,C06,C07, C08, C09, C10, C11, C12, C30, E00, E01, E02, E03, E04,……., E41.

Note that the suitable explanations and suggested action will be provided when we enter the corrected error code as in the default of error code above.

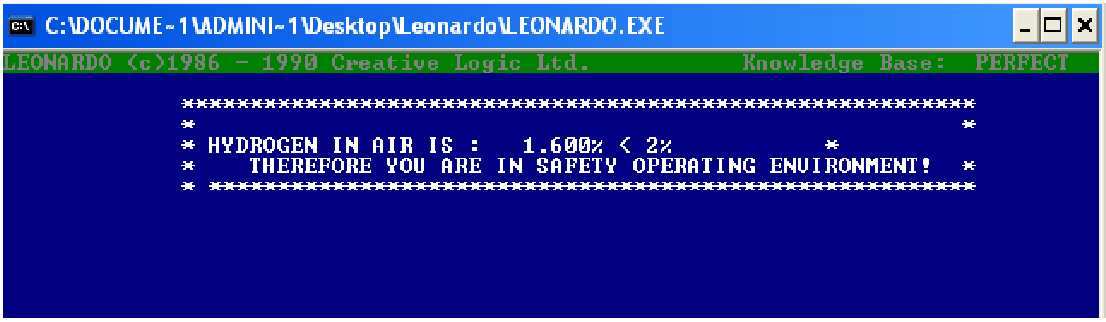
Next, for example if I choose the error code is E30, the expert system will be automatically call the “E30.txt” file which is saved in the same directory with this program and the screen will be shown as below:



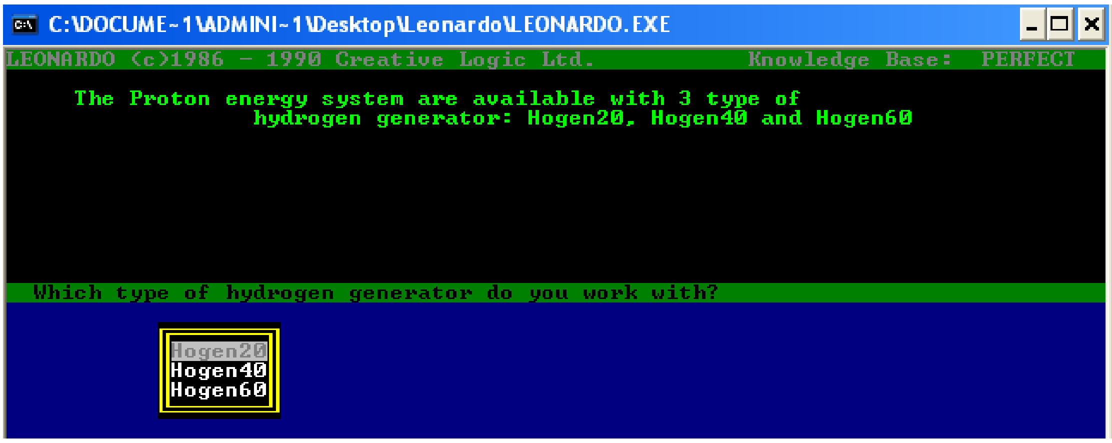
If the chosen action is “conversion”, the follow screen will appear as below:



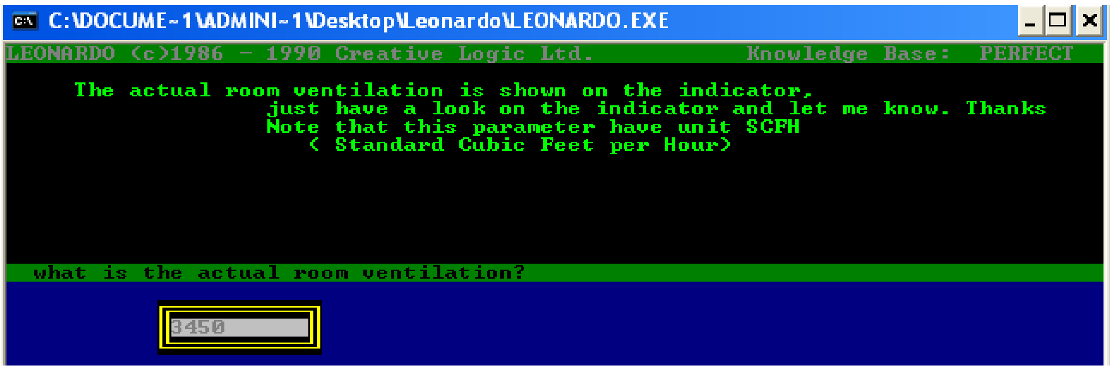
The allow value for lower flammable limit is >0 and < 100 (because maximum is 100%) . Therefore the user can only enter the value in this range . If the example value enter is “40” then the result is :



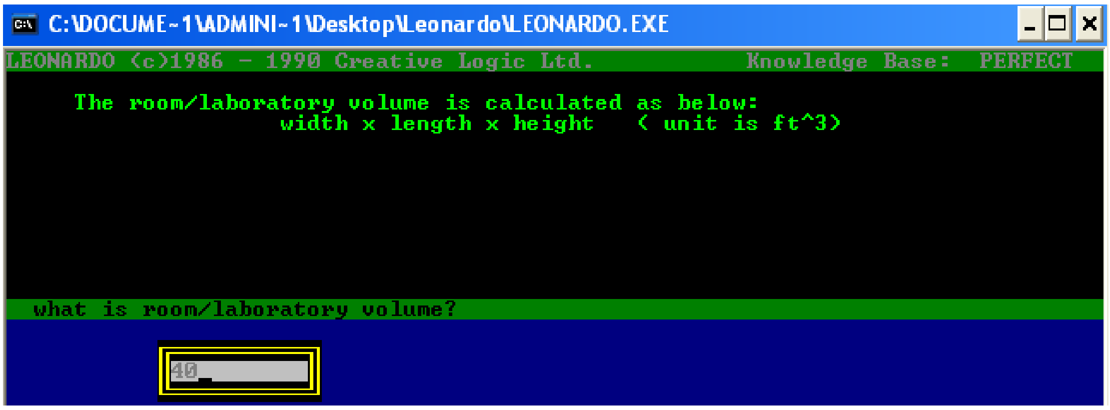
If choose action is “ calculate_ventilation_requirement”, the follow screen will appear as below:



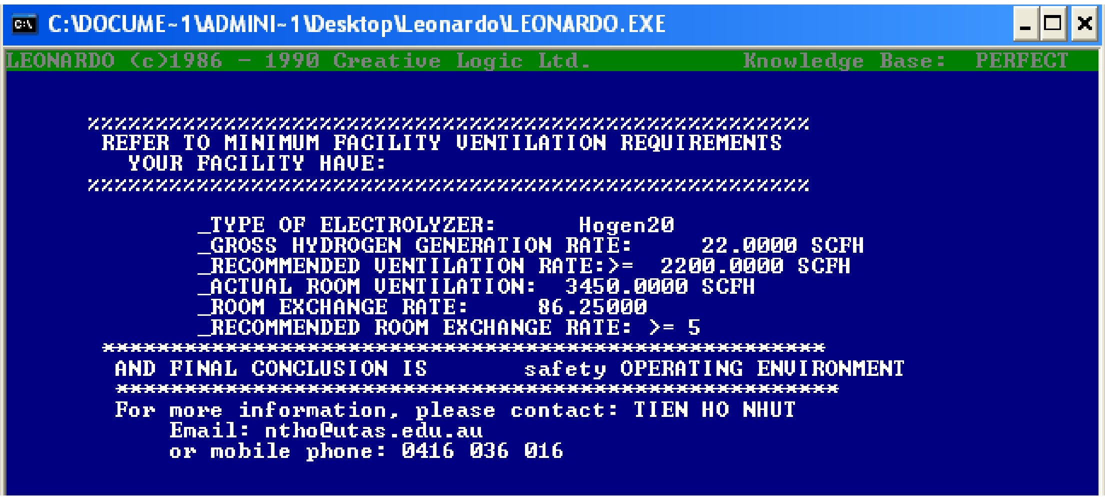
If we choose type “Hogen20” – for example, the next question as below:



We try the value “3450”, and then the next question as below:



If we enter the room/laboratory volume is "40" then the result as below:



All of The test cases were completed successful and with corrected results were obtained.

1.8.6 User's Guide

Getting Started

The 'Hydrogen safety instruction guide expert system' was developed and operated using the Leonardo expert system shell which is available from the Internet and some education institutions and department.

In initialise stage of Leonardo, the main menu is located and opened at the top of the screen and we can use the arrow keys as well as enter key to access these menus. Beside that we also can use the 'F#' keys to access various functions of the expert system shell.

Loading the program

It will be easier to load the expert program file (complete.pkb) into the same directory or same folder of the Leonardo system.

Once the “complete.pkb” file in the same directory/folder with Leonardo system, we are now double-clicking on the ‘Leonardo.exe’ file which will either load in a DOS window or as a full screen depending upon your own system settings. The screen will be shown as below:

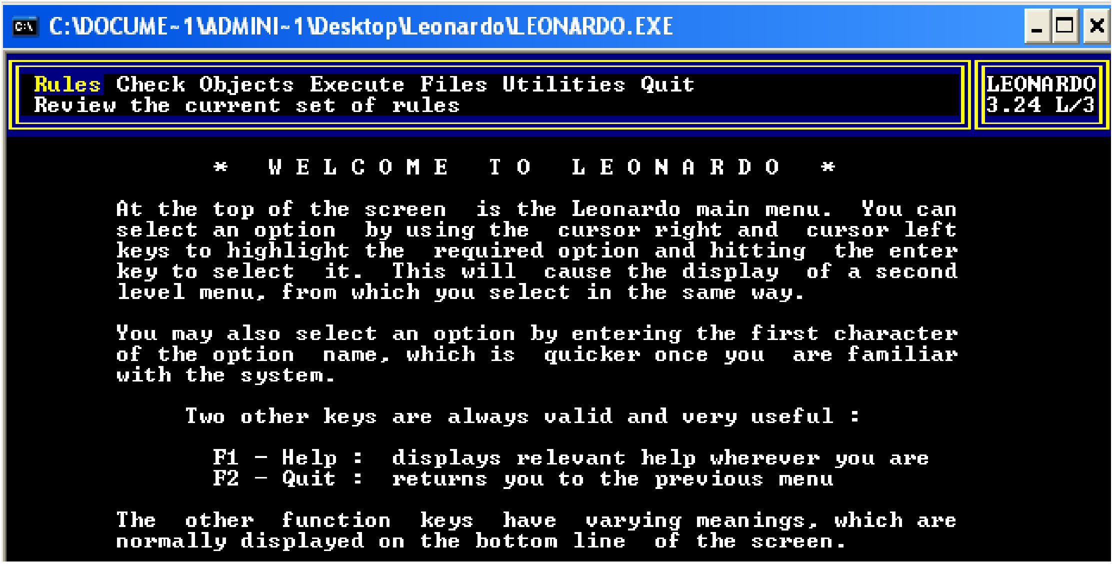


Figure: Main menu screen

By using the left / right arrow keys, we now move the cursor to ‘Files’ and press enter. This will access to a display menu where the programs which Leonardo can load to its database. The file loading presentation screen will be shown as below:

Figure: File loading representation

Press ‘Enter’ to access the load action to load a new file and then using the up and down arrow keys again, move the cursor to ‘COMPLETE’ and press enter to open this file.

After that the knowledge base will be load into the Leonardo expert system shell and the screen that indicate the file operate successfully as below:

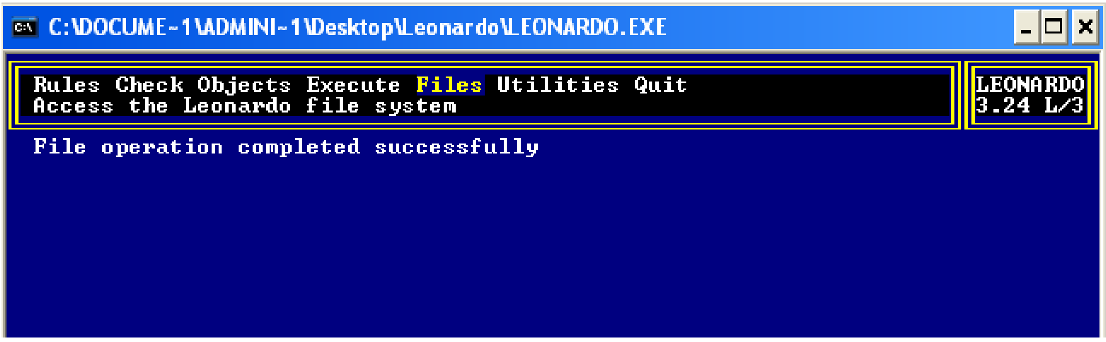


Figure: File loaded representation

Move the cursor to ‘check’ and press enter. Then press ‘Enter’ again on the option ‘summary’. This will checking the program to make sure that everything is correct.

Move the cursor to ‘execute’ and press enter. Then press ‘enter’ again on the option ‘Default’. This will start our expert system.

Running the program

The program is simple to use and the user just only using the up / down arrow keys ,‘Enter’ key and follow the instruction question in the bottom center of the screen as indicated which is prompts the user to enter the relevant data to the system.

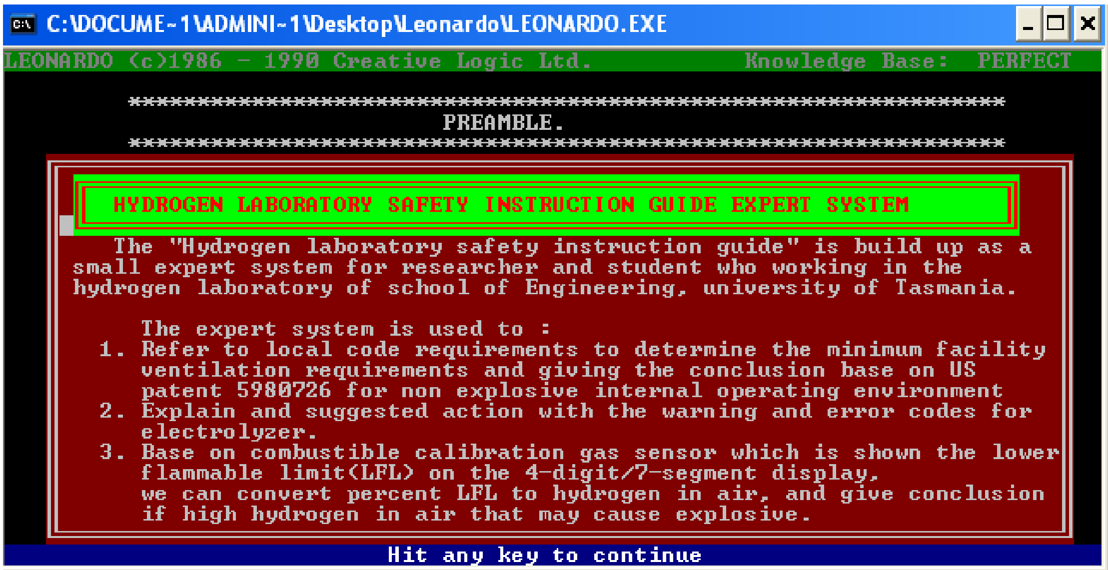


Figure: ‘Hydrogen laboratory safety instruction guide expert system’ main screen

The main question screens are divided into three sections:

The top section (text in green) provides the user with some general information in regard to the question (More information can be provided by pressing F7, if the expansion is available)

The middle section with the black text will show the question prompts the user to enter the relevant data to have an appropriate answer/ instruction.

And finally the section with yellow box will enable the user to enter of choose the relevant data for the question presented in the middle section.

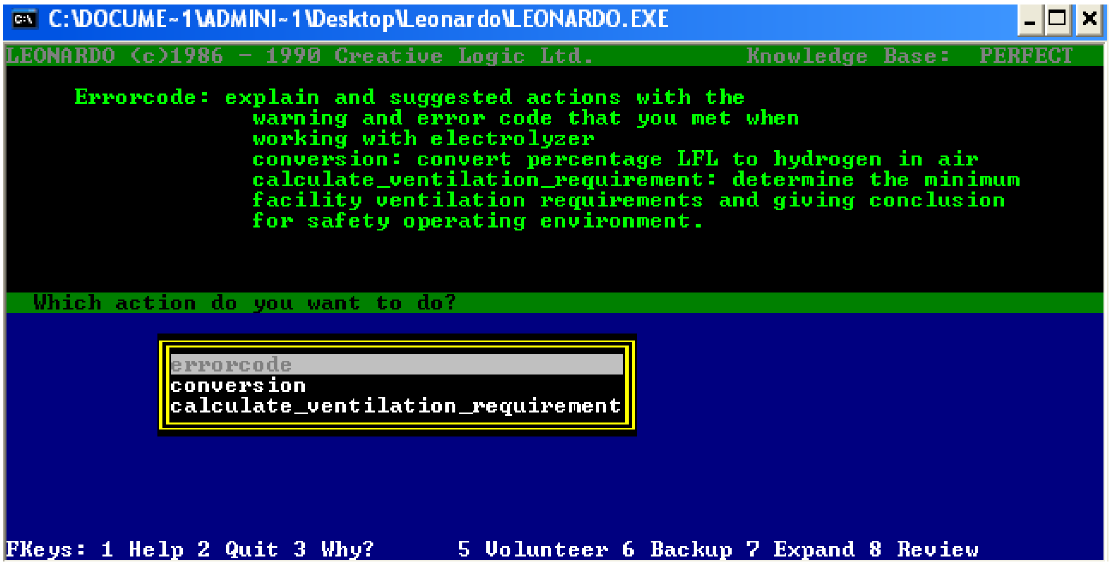


Figure: Generalist view of program

The question will be ask step by step to ascertain more information and provide an accurate result with display the end screen conclusion/explaining the suggested action requirements.

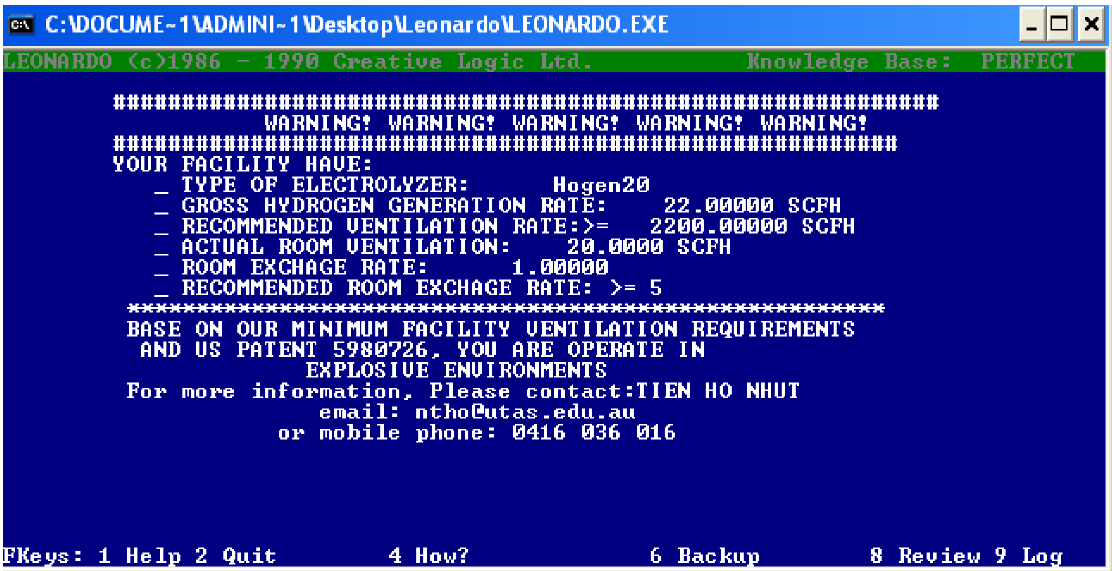


Figure: Generalist view of example final screen

Once the program has given a suitable solution, and is presented in the screen as above, we will return to Leonardo by using F2 key which is mean "Quilt". Note that, if we press 'Enter' immediately will restart the program.

Trouble Shooting

Due to the design of the program, there should be a reason for false error code to be entered in the action "errorcode". Because of this, the program is always able to draw a conclusion from the data that the user has input except the wrong error codes enter into the database as mention above.

Glossary

The following is an alphabetical index containing shortenings, technical terms and miscellaneous words that have been used in this program. Note that words in *Italic* are explained elsewhere in the glossary, while words in (parentheses) are descriptions of shortenings.

Design and Development of a Hydrogen Laboratory	document about the development of the *Hydrogen Laboratory* made by Dr. Vishy Karri
detonability limit	explosive limit, gas/air ratio where explosion can occur
electrolyser	hydrogen generator, a machine that produces hydrogen from water and electricity
HART Group	a research group working in the Hydrogen Laboratory, it consists of postgraduates and researchers from UTAS and it is supervised by Dr. Vishy Karri
HART Program	(Hydrogen Allied Renewable Technology) joint hydrogen research program between UTAS and Hydro Tasmania
hydrogen	hydrogen gas throughout this project
hydrogen generator	see electrolyser
Hydrogen Laboratory	(Hydrogen Energy Research Facility) new research facility at UTAS concerning hydrogen technology
hydrogen/water phase separator	a device in the electrolyser that separates the water from the hydrogen
LFL	(lower flammable limit) see flammability limit

oxygen/water phase separator	a device in the electrolyser that separates the oxygen from the water
P&ID Tag	(piping and instrumentation diagram tag)
PEM	(proton exchange membrane) the electrolyte in a PEM electrolyser, it consists of a solid flour polymer (Teflon) that has been chemically altered to contain sulphonic acid groups
PEM electrolyser	electrolyser that uses a PEM
product hydrogen	the hydrogen that exits the product hydrogen port
SCFH	(standard cubic feet per hour) 1 SCFH = 28.3 litres
sensor calibration hood	cup used to connect calibration bottle with sensor
test rig	an area in the Hydrogen Laboratory dedicated for setup of an engine
UTAS	(University of Tasmania)

1.8.7 Discussion

Software can be developed in the form of an expert system where information can easily and quickly enter into a knowledge base. From here, it can be accessed by question prompts where the user provides an appropriate response. The system can then have the ability to access the knowledge base and provide an accurate answer as required.

The development of a system, which could provide these results, would also be useful for visitor or person who did not familiar with hydrogen safety operating environment. The system is simple enough such that people who less knowledge could use the system to try and identify safety instruction guide as well as error codes and suggested action available and then cross reference this result with a proven analysis. This activity would enhance necessary 'problem solving' skills being developed in the hydrogen laboratory, and also provide information technology skills as well as step by step using computer programming language to save and extract database for using in the required later on hydrogen laboratory.

A system like this would also be invaluable to an interactive hydrogen safety and instruction guide exhibition where visitor and researcher alike would have the opportunity to become involved in 'hydrogen safety requirement and instruction guide' for a short time and helping fix the error of electrolyser in hydrogen laboratory.

1.8.8 Conclusion

In conclusions, we can say that the particular consultation paradigm selected was very appropriate for expert system implementation. There was more than enough information in regard to hydrogen safety instruction guide and suggested action to fix error codes as well as also adequate 'expert' information available so that there are basic series of questions could be developed in order to obtain a specific and particular solution.

Upon three prototypes example for this system within the Leonardo shell, as some experience was required to understand the corrected operating system and a successful program had been developed and was tested extensively by using the flow chart developed previously. Each objective within the flow chart was tested and the system was found to be correct as expected.

Through out the process for building small expert system, it would require considerable effort to determine problem characteristics, identify participants, specify objectives, determine resources need for building the system. As we looking at the previous example and through out a lot of testing procedures, this program achieves all the objectives that were outlined, and meets all the criteria for a successful rule based expert system.

1.8.9 Appendices of hydrogen safety advisor program

Appendix 1 – Typical % LFL hydrogen in air conversion

The acceptable range of calibration gas is 30% to 50% LFL. The first two digits of the display will change to reflect the selection. Values increment by 1% LFL. [1]

% LFL	% Hydrogen in Air	% LFL	% Hydrogen in Air
50	2	39	1.56
49	1.96	38	1.52
48	1.92	37	1.48
47	1.88	36	1.44
46	1.84	35	1.4
45	1.8	34	1.36
44	1.76	33	1.32
43	1.72	32	1.28
42	1.68	31	1.24
41	1.64	30	1.2
40	1.6		

Table 1: Typical %LFL hydrogen in air conversion

Appendix 2 – possible error code displays, their cause, and the system response, troubleshooting Diagnostic Procedures tables

The HOGEN hydrogen generator provides automatic shutdowns through continuous monitoring of critical operating parameters. If a parameter is not within its specified limits, the controller takes the appropriate action to the HOGEN generator gas generation process. Upon shutdown of the unit, the controller shows the error code for the type of shutdown on the 4-digit/ 7-segment display.

Code	Description	Default Limit	Sensor (P&ID Tag #)	Time Activated
E-00	Manual Shutdown	Switch Closure	Stop Switch	On Power Up
E-01	Cell Voltage High	> (# Cells x 3)	N/A	On Generate + 5s
E-02	Cell Voltage Low	< (# Cells x 0.5)	N/A	On Generate + 5s
E-03	A200 Empty	< Empty Level	LS201-1	On Start Switch
E-04	A200 Flooded	> Flooded Level	LS201-4	On Drain + 30s
E-05	A300 Empty	< Empty Level	LS301-1	On Generate
E-06	A300 Flooded	> Flooded Level	LS301-4	On Generate + 15/30s
E-07	Poor Water Quality	< 1 MΩ-cm	RS209	On Circ Test + 20s
E-08	Failed Water Quality Sensor	> 18 MΩ-cm	RS209	On Circ Test + 20s
E-09	Low Recirculation Flow	< 3.79 LPM	WS207	On Circ Test + 10s
E-10	System Pressure High	> Pressure Set Point + 50 psig	PT307	On Power Up
E-11	System Pressure Low	< Pressure Set Point - 50 psig	PT307	On Pressurize + 30s
E-12	Product Pressure High	> Product Pressure Set Point + 20 psig	PT312	On Power Up
E-13	Hydrogen Leak Detected	> 30% LFL	CG220	On Power Up
E-14	System Temperature High	> 60°C	TS218	On Circ Test + 10s
E-15	A200 Pre-Start Timeout	> 2 Hours	LS201	On Power Up + 2 hrs
E-16	A300 Pre-Start Timeout	> 2 Hours	LS301	On Power Up + 2 hrs
E-17	Rectifier #3 Fault	Fault Signal High	PWR102-3	On Generate + 5s
E-18	Cabinet Purge Pressure Low	< 0.2" Water Column	PS121	On Power Up + 10s
E-19	Rectifier #1 Fault	Fault Signal High	PWR102-1	On Generate + 5s
E-20	Rectifier #2 Fault	Fault Signal High	PWR102-2	On Generate + 5s
E-21	Processor Fault	Internal Watchdog Failure	N/A	On Power Up
E-22	FPGA Fault	Control Board		All States
E-23	High Current	> 150 Amps	PWR102-1	On Generate
E-24	A300 Flooded Restarts	1 Restart Max	N/A	After 1 E-06
E-25	CG Sensor Out of Calibration	Calibration Past Due	N/A	On Circ Test + 45s
E-26	E-Stop Circuit Fail	E-Stop (Open)	M101	On Power Up
E-30	System Temperature Low	< 5°C	TS218	On Circ Test + 10s
E-31	State Machine Fault	Control Board		All States

Table 2: The possible error code displays, their cause, and the system response

P&ID TAG	PART NAME	PROTON PART NO.
A200	Oxygen/Water Phase Separator	54-0500-0034
A300	Hydrogen/Water Phase Separator	52-0102-0000
BPR310	Back Pressure Regulator	02-2400-0001
CD339	BEKOMAT® Condensate Drain	54-0503-0022
CG220	Combustible Gas Detector	54-0503-0021
CP205	Circulation Pump	54-0500-0041
CV222	Oxygen Vent Check Valve	02-2500-0011
CV227	Condensate Drain Check Valve	02-2500-0001
CV302	Hydrogen Vent Check Valve 1	02-2500-0014
CV305	Hydrogen/Water Phase Separator Drain Check Valve	02-2500-0015
CV311	Product Hydrogen Check Valve	02-2500-0014
CV315	Hydrogen Vent Check Valve 2	02-2500-0014
CV327	Dryer Purge Check Valve	02-2500-0010
CV505	Water Feed Check Valve	02-2500-0012
CV512	Water Startup Check Valve	02-2500-0006
EM100	Electrolyzer Cell Stack	HOGEN 10 Cell Stack: 54-0201-b010
		HOGEN 13 Cell Stack: 54-0201-b013
		HOGEN 20 Cell Stack: 54-0201-b020
		HOGEN 25 Cell Stack: 54-0201-b025
F210	Cell Stack Water Filter	02-3001-0004
F228	Orifice Screen	02-3300-0020
F304	Hydrogen Vent Filter	02-3001-0006
F306	Hydrogen/Water Phase Separator Water Filter	02-3001-0025
F313	Hydrogen Management Inline Hydrogen Filter	02-3001-0006
F328	Coalescing Filter	04-0200-0000
F506	System Water Filter	02-3001-0003
GB208	Guard Bed Resin Cartridge	02-3001-0007
HX203	Heat Exchanger	52-3100-0000
IN338	Dielectric Union	02-0203-0006
LS201	Oxygen/Water Phase Separator Level Sensor	58-1100-0002
LS301	Hydrogen/Water Phase Separator Level Sensor	08-1100-0001
OR225	Oxygen Sample Orifice	02-0201-0104
OR309	Hydrogen/Water Phase Separator Low Flow Drain Orifice	HOGEN 20: 02-3300-0007
		HOGEN 40: 02-3300-0006
OR325	Hydrogen Vent Orifice	02-3300-0001
OR330	Hydrogen Dryer Orifice	HOGEN 20: 02-3300-0005
		HOGEN 40: 02-3300-0003
PS121	Cabinet Pressure Switch	08-0201-0000
PT307	System Pressure Transducer	08-1100-0002
PT312	Product Pressure Transducer	08-1100-0002
RS209	Water Quality Sensor	54-0503-0019
RV308	Hydrogen Relief Valve	02-2503-0001
SV211	Drain Valve	02-2501-0002
SV303	Low Flow Drain Valve for Hydrogen/Water Phase Separator	08-1700-0001
SV329	Vent Valve	08-1700-0002
SV340	High Flow Drain Valve for Hydrogen/Water Phase Separator	08-1700-0001
SV510	Water Feed Valve	02-2501-0001
SV511	Water Startup Valve	02-2501-0003
TS218	System Thermistor	58-1100-0001
V223	Oxygen/Water Phase Separator Vent Valve	02-2502-0001
WS207	Low Flow Switch	54-0503-0020
X334	Pressure Swing Dryer	54-0503-0025
Z350	Hydrogen Gas Management Manifold	54-0500-0000

Table 3: **P&ID Cross Reference Table with PROTON Part Numbers**

Error	Description	Possible Cause	Suggested Action
E-00	Manual Shutdown	Manual stop button activated	
E-01	High Voltage Shutdown on the Cell Stack	Cell stack voltage is too high	Verify the voltage across the cell stack with a multimeter. In debug mode, verify P-02 is correct for the cell count.
		Offset and gain values are incorrect	If software diagnostics is available, verify the Stack Voltage calibration offset and gain values are at default.
E-02	Low Voltage Shutdown on the Cell Stack	Cell stack voltage is too low	Verify the voltage across the cell stack with a multimeter. In debug mode, verify P-02 is correct for the cell count.
		Offset and gain values are incorrect	If software diagnostics is available, verify the Stack Voltage calibration offset and gain values are at default.
E-03	Oxygen/Water Phase Separator Empty	Water Feed Valve (SV510) is not operational	Verify D16 on the control board is off. Verify the water feed valve (SV510) is turning on (D36 on the control board). If the water feed valve is not turning on, verify fuses F11 and F2 are functional.
		Level Sensor Switches on LS201 error	Verify the high and flood switches are not engaged (D18 should not be lit and D19 should be lit on the control board).
E-04	Oxygen/Water Phase Separator Flooded	Drain Valve (SV211) is not operational	Verify D19 on the control board is off. Verify the drain valve (SV211) is turning on (D32 on the control board). If the drain valve is not turning on, verify fuses F7 and F2 are functional.
		Level Sensor Switches on LS201 error	Verify the low and empty switches are not engaged (D17 should not be lit and D16 should be lit on the control board).
		Water Feed Valve (SV510) failure	The water feed valve should not be on (D36 on the control board). If the water feed valve is not turning off, verify the low and empty switches are not engaged.

Error	Description	Possible Cause	Suggested Action
E-05	Hydrogen/Water Phase Separator Empty	Level Sensor Switch on LS301 failure	Verify D20 on the control board is off (if the water level is below empty D20 should be off). If D20 is on, but should not be on verify that fuse F16 is functional.
		Drain Valve (SV303/SV340) failure	Verify the high and low flow drain valves (SV340 and SV303) are not staying on (D29 and D30 on the control board).
		Level Sensor Switches on LS301 error	If the valves are not turning off, verify the high and flood switches are not engaged (D22 should not be lit and D23 should be lit on the control board).
E-06	Hydrogen/Water Phase Separator Flooded	High and Low Flow Drain Valves (SV340/SV303) are not operational	Verify D23 on the control board is off. Verify the high and low flow drain valves (SV340 and SV303) are able to turn on (D29 and D30 on the control board). If the valves are not turning on, verify fuses F2, F4, and F5 are functional.
		Level Sensor Switches on LS301 error	Verify the low and empty switches are not engaged (D21 should not be lit and D20 should be lit on the control board).
E-07	Poor Water Quality	Set point error	On startup, verify the system goes into a flush sequence. In debug mode, verify P-06 water quality is set to its default (1.0 megaohm-cm).
		Water Quality Sensor (RS209) error	Test actual water quality to verify the water quality.
		Offset and gain values are incorrect	If software diagnostics is available, verify the Water Quality calibration offset and gain values are at default.
E-08	Failed Water Quality Sensor	Wiring error	Verify the connection between the harness connector and sensor connector is intact.
		Failed connection between control board and Water Quality Sensor (RS209)	To verify the system will still operate, disconnect the water quality sensor connector from the harness and short the 2 pins on the harness connector. On startup, the system should enter a flush cycle.
		Offset and gain values are incorrect	If software diagnostics is available, verify the Water Quality calibration offset and gain values are at default.
E-09	Low Recirculation Flow	Circulation Pump (CP205) failure	Verify D24 on the control board is off. Verify the pump is on (D56 on the control board). If the pump is not turning on, verify fuse F3 is functional.
		Flow Switch (WS207) error	If the pump is on, verify the actual water flow rate by using a flow meter to measure the flow rate (< 3.79 LPM is a failure).
		Wiring error	If the flow rate is above its failure rate, verify the wiring is intact between the flow sensor and the harness connector.

Error	Description	Possible Cause	Suggested Action
		Circulation Pump (CP205) not primed.	With water in the A200, disconnect the tubing from the outlet of the pump. Allow water to flow out of the pump, reconnect the tubing and re-fasten the hose barb clamp.
		Failed connection between control board and Flow Switch (WS207)	To verify the system will still operate, disconnect the flow switch connector from the harness and short the 2 pins on the harness connector. The system should start.
E-10	System High Pressure	Set point error	In debug mode, verify the system pressure set point P-00 is set correctly. Verify the set point P-07 is set to the system default.
		Backpressure Regulator (BPR310) error	Verify the backpressure regulator (BPR310) is set properly.
		System Pressure Transducer (PT307) error	Verify the voltage at TP53(+) and TP1(-) is between 0.5 – 4.5 VDC.
		Offset and gain values are incorrect	If software diagnostics is available, verify the System Pressure calibration offset and gain values are at default.
E-11	System Pressure Low	Set point error	In debug mode, verify the system pressure set point P-00 is set correctly.
		Backpressure Regulator (BPR310) error	Verify the backpressure regulator (BPR310) is properly set.
		System Pressure Transducer (PT307) error	Verify the voltage at TP53(+) and TP1(-) is between 0.5 – 4.5 VDC.
		Misconnection	Verify the wiring is intact between the pressure transducer (PT307) connector and the harness connector.
		Offset and gain values are incorrect	If software diagnostics is available, verify the System Pressure calibration offset and gain values are at default.
E-12	Product Pressure High	Set point error	In debug mode, verify the product pressure set point P-01 is set correctly. Verify the set point P-08 is set to the correct default.
		Product Pressure Transducer (PT312) error	Verify the voltage at TP52(+) and TP1(-) is between 0.5 – 4.5 VDC.
		Offset and gain values are wrong	If software diagnostics is available, verify the Product Pressure calibration offset and gain values are at default.
E-13	Hydrogen Leak Detected	Set point error	In debug mode, verify the combustible gas set point P-09 is set to 30%.
		Combustible Gas Sensor (CG220) out of calibration	Take voltage readings between TP54(+) and TP1(-). Verify the voltages to be approximately per the following LFL levels: 50% LFL = -2.0 ± 0.1 VDC 25% LFL = -2.2 ± 0.1 VDC 0% LFL = -2.4 ± 0.1 VDC
		Offset and gain values are wrong	If software diagnostics is available, verify the calibration offset and gain values are at default.

Error	Description	Possible Cause	Suggested Action
		Hydrogen assemblies are leaking	Verify there are no leaks in the system, by doing a leak check with a hand held gas detector and/or liquid leak detector.
E-14	System Temperature High	Air filter needs replacement	Check the air filter and replace if necessary.
		Set point error	In debug mode, verify the system temperature set point P-10 is set at 60.
		Thermistor (TS218) error	Verify the voltage at TP19(+) and TP1(-) is less than 1.7 VDC. Compare the measured temperature to an independent thermometer reading.
		Blower error	Verify the blower is turning on. If blower is not turning on, verify fuses F102 and F104 on the terminal block are functional. Verify the blower wiring is intact.
		Filter fouling	Verify there is not fouling at the internal mesh filters and heat exchanger coils.
E-15	Oxygen/Water Phase Separator Pre-Start Timeout	Operator error	Verify the water supply to the system is turned on.
		Valve failure	Verify the water feed valve (SV510) is turning on (reference error code E-03). Verify the drain valve (SV211) is not on (D32 on the control board).
E-16	Hydrogen/Water Phase Separator Pre-Start Timeout	Operator error	Verify the water supply to the system is turned on
		Valve failure	Verify the high and low flow drain valves (SV340 and SV303) are off (reference error code E-05). Verify the water feed valve (SV510) is turning on (reference error code E-03).
		Water Startup Valve (SV511) failure	Verify the water startup valve (SV511) is turning on (D35 on the control board). If the water startup valve is not turning on, verify the fuses F10 and F2 are functional.
E-17	Rectifier #3 Fault (Only applies to HOGEN 60)		Power down the unit for at least 5 seconds and restart.
		Wiring error	Verify the wiring to the power supply is intact.
		Configuration error	If error occurs on a HOGEN 20 or HOGEN 40, a configuration file update is required. Contact PROTON.
E-18	Low Pressure Purge	Structure failure	Verify that all doors and covers are securely closed.
		Air filter fouling	Check the air filter and replace it if it is fouled.
		Blower failure	Verify the blower is turning on. If the blower is not turning on reference error code E-14.
		Pressure purge switch connection error	Verify the wiring is intact to the pressure purge switch. Verify the tubing to the pressure purge switch is intact.

Error	Description	Possible Cause	Suggested Action
E-19	Rectifier #1 Fault		Power down the unit for at least 5 seconds and restart.
		Wiring error	Verify the wiring to the power supply is intact.
E-20	Rectifier #2 Fault		Power down the unit for at least 5 seconds and restart.
		Wiring error	Verify the wiring to the power supply is intact.
E-21	Processor Fault	Control board error	Power down the unit for at least 5 seconds and restart. Enter debug mode and re-enter default adjustable parameters P-00 to P-11.
		Configuration error	If software diagnostics is available, attempt to reload Application file, FPGA, Configuration file and Calibration file.
E-22	FPGA Fault	Control board error	Power down the unit for at least 5 seconds and restart. Enter debug mode and re-enter default adjustable parameters P-00 to P-11.
		Configuration error	If software diagnostics is available, attempt to reload Application file, FPGA, Configuration file and Calibration file.
E-23	Over current Fault	Control board error	Verify actual current with an amp clam and compare the reading to the displayed current.
		Offset and gain values are wrong	If software diagnostics is available, verify the Stack Current calibration offset and gain values are at default.
E-24	A300 Flooded Restarts (Manual Draining of the A300 is required per Appendix G.	Excessive Manual Stops in Vent Mode	More than 6 manual stops while the system is operating in vent mode can result in a flooded A300. If possible, when multiple manual stops are required, wait until the system has entered the generate state (after 60 seconds of initial hydrogen generation) prior to shutting down.
		Low system pressure	Monitor system pressure on startup. If system pressure is low, check for leaks.
		Power Supply Failure	Verify current is being applied to the cell stack. If there is no current, the electrolyzer power supplies may require replacement / repair.
		Blocked Drain Orifice	If during system run (Generate Mode) the A300 Low Flow SV303 is on for more than 5 minutes, the drain orifice may be blocked. Replace the A300 as required.
E-25	CG Sensor Out of Calibration	Combustible Gas Sensor (CG220) requires calibration.	Calibrate the combustible gas sensor.

E-26	E-Stop Circuit Failure	Contactor M101 is stuck closed and not opening on demand.	Remove power from the system using CB101. Place E-Stop in the normal operating position and reapply power using CB101. If problem persists, M101 may require replacement.
		Broken wire 01128 or 01129.	Perform continuity check on wires 01128 and 01129 from the M101 auxiliary contact to PCB101 connector J9. Repair as necessary.
E-30	Low System Temperature	Disconnected / Failed Thermistor	Verify TS218 mating connectors are secure. If the connection is good, the thermistor may require replacement.
		Temperature Offset	Verify ambient temperature is greater than 5 degrees C. Replace thermistor as required.
E-31	State Machine Fault	Control board error	Power down the unit for at least 5 seconds and restart. Enter debug mode and re-enter default adjustable parameters P-00 to P-11.
		Configuration error	If software diagnostics is available, attempt to reload Application file, FPGA, Configuration file and Calibration file.

Table 4: Troubleshooting Diagnostic Procedures

References

1. “Hogen installation & operation instructions”, Proton Energy system Inc.
2. “Installation of a Hydrogen Generator”, Mathias Guldager Petersen, 11-2004
3. Day to day use of the hydrogen laboratory school of Engineering, University of Tasmania, conducted on 18th march 2005.
4. www.protonenergy.com

2 APPENDIX 2 HYDROGEN CAR SECTION

2.1 Comparison of hydrogen conversion with numerous Australian and International standards[4]

The detailed comparison of hydrogen conversion with numerous Australian and International standards is attached in this appendix.

Comparison of Applicable Standards for Hydrogen Car Project			
NFPA 52:2005 Vehicular Fuel Systems (Natural Gas and Hydrogen) - USA			
Item	Requirement	As Installed	Complies?
Gaseous detection	Required (1/4 LEL)	Fitted (1/10 and 1/2 LEL)	Yes (in lieu of enclosure from CNG standard)
Pressure vessel compartment	Not required	Not installed	Yes
Pressure relief vented to atmosphere	Required	Fitted	Yes
Pressure relief vented to safe area	Required	Fitted	Yes
Pressure vessels without temp protection	spring loaded pressure relief	Fitted	Yes*
Regulator low pressure relief	Required	Fitted	Yes
Fuel line corrosion inhibition	Required	316 Stainless Steel	Yes
Fuel Line burst pressure	> 4x rated pressure	> 4x rated pressure	Yes
Fuel line Standard	ANSI/ASME B31.3	ANSI/ASME B31.3	Yes
Tapered threads	Only if unavoidable	Only where unavoidable	Yes
Number of piping joints	minimised	minimised	Yes
Hose Corrosion, etc	Resistant to exposure to H2	Resistant to exposure to H2	Yes
Vehicle fuelling connection	SAE J2600	SAE J2600	Yes
* Only applicable when pressure vessel valve is open.			
AS/NZS 2739:2003 Natural Gas (CNG) Fuel Systems for Vehicle Engines			
Item	Requirement	As Installed	Complies?
Original Engine Management System	To meet emission limits	No Change	Yes
Inlet Manifold	To meet emission limits	As close to original spec as possible	Very likely
H2 Emissions	To meet emission limits	Lower emissions than petrol	Yes
Cylinder rated working pressure	165 bar min.	165 bar (filled to 137 bar)	Yes
Use of removable cylinders	Only if no refuelling available	No refuelling available	Yes
Cylinder colour if in sunlight	White	Red (comply with cover added)	Yes
Cylinder Valve Standard	AS 2473	AS 2473	Yes
	Required	Fitted	Yes
Pressure relief	3000 PSI CNG	350 bar H2	Yes
Refuelling Connection	Required	integral with receptacle	Yes
Refuelling non-return valve	Required	Fitted	Yes
Service Isolation Valve	Required	Fitted	Yes
Fuel Filter	Required	Fitted	Yes
Auto Fuel Shut-off	Reasonable	OK for small to medium collision	Yes
Regulator impact protection	within 500mm	Okfor approximate 500 mm	Yes as complied with US NFPA Standard)
Regulator close to fuel shut-off	Secure	OK	Yes
Regulator mounting	Electrical	Electrical	Yes
Fuel Pressure Indicator	Required	Fitted	Yes
Cylinder compartment	External to passenger cabin	Extra devices located externally	Yes*
Cylinder safety device discharge	500 mm^2	> 500 mm^2 (vents in rear of car)	Yes
Ventillation area	> 75 mm from exhaust	> 75 mm from exhaust	Yes
Ventillation position	Required	Fitted	Yes

[4] These comparisons have been made during the desired process of hydrogen car project team and supervisor.

Cylinder mounting reinforcement	Resistant to loosening	nylock nuts	Yes
Cylinder mounting bolts/nuts	4.6	8.8	Yes
Cylinder mounting bolt class	20 (long), 8 (lat), 4.5 (vert)	20 (long), 8 (lat), 4.5 (vert)	Yes
Cylinder mounting G-force	> 200 mm within rearmost steel	> 200 mm	Yes
Cylinder location	> 100 mm from outer body skin	> 100 mm from outer body skin	Yes
Cylinder fitting location	Manufacturer's instructions	Fitted	Yes
Cylinder exposure to sun	Heat shield if < 150 mm	Fitted	Yes
Heat shielding of equipment on fire wall	Burst pressure 4x working pressure	Burst pressure > 4x working pressure	Yes
Fuel piping Fuel piping screwed joints	Taper screw threads SAE J1453	Taper screw threads Swagelok	Yes Yes, equivalent or better standard
Ground Faced Unions	Shortest practical	Shortest practical	Yes
Piping route	Use of vehicle body	Vehicle body and rubber hose	Yes
Piping protection	< 600 mm	< 600 mm	Yes
Piping supports	minimised	minimised	Yes
Number of piping joints	Loomed	Loomed	Yes
Wiring			
* Only applicable when pressure vessel valve is open.			
AS 4838-2002/ISO 11439:2000 Gas cylinders - High Pressure Cylinders for the On-Board Storage of Natural Gas as a Fuel for Automotive Vehicles			
	CNG Standard for 200 bar	Adjusted for H2 at 137 bar	Maximum used for this cylinder in other applications
Item	200 bar	137 bar	165 bar
Settled Pressure at 15C	200 bar	137 bar	165 bar
Working pressure	260 bar	178.1 bar	Factory burst Disc set at 245 bar
Maximum Filling Pressure			410 bar Hydrogen
Test Pressure	300 bar 450 bar (safety factor 2.25)	205.5 bar 308.25 bar	495 bar Nitrogen > 495 bar
Burst Pressure	Top, centreline	Top, centreline	Top, centreline
Openings	Treated	Treated	Treated
Heat treatment	Paint	Paint	Paint
Corrosion protection	At least 14%	At least 13%	At least 13%
Sulfide stress cracking test	Leak or 45000 cycles	Leak or 45000 cycles	No leak at 10000 cycles
Leak test	200 bar Nitrogen Required	137 bar Nitrogen Required	165 bar Nitrogen Required
Hydraulic test	Required	Required	Required
Hydrostatic pressure burst test	Required	Required	Not required

2.2 Professional Lambda Meter and Lambda Sensor[5]

[5] This section is referenced from: MoteC Parts Catalogue, Revision 1.24, February 2007.

PLM (Professional Lambda Meter), Kits and Sensors

The *MoTeC* Professional Lambda Meter (PLM) accurately determines exhaust gas mixture strength over a wide range of engine operating conditions with a fast response time. This is quick and easy to use, whilst allowing a calibration engineer all of the power and configurability required for OE emissions development and certification work. The PLM can also be configured as a Lambda input into any MoTeC ECU for use in Quick Lambda, Lambda Was, Data Logging or Closed Loop Lambda control, instead of needing the ECU's Lambda option enabled.
Weighing only 135 gms and with a robust aluminium enclosure it can be conveniently mounted singularly, or in multiples, in almost any application. The operating range of the device is between 0.7 and 32.0 Lambda. For Gasoline/Petrol this equates to an Air/Fuel Ratio range of 10.3:1 to 470:1.
The display may be set to show Lambda, Air Fuel Ratio or Equivalence Ratio for any sensor compatible fuel (Gasoline/Petrol, Alcohol, Gas, Diesel or "blend" fuel as defined by the user). The resolution of the display (decimal points), display update rate, display filtering, backlight intensity may all be defined by the user with the Windows setup software provided.
The *MoTeC* Professional Lambda Meter provides an differential Analogue Voltage Output that may be connected to an ECU, Analog meter or other measurement instrument such as a Data Logger or Chart Recorder. The output may be defined by the user to be linear or non-linear in relation to the measured units. The PLM also supports 1mbit CAN and RS232 data links to devices such as *MoTeC* Dash Logger or ECU for transmission of sensor and diagnostic data. Comprehensive diagnostic and status channels are provided.

LSU PLM kit

NTK UEGO PLM kit

15004 PLM – Meter Only
15003 PLM – Pro Lambda Meter Kit with LSU, 2.5m
15003LL PLM – Pro Lambda Meter Kit with LSU, 5m
15002 PLM – Pro Lambda Meter Kit with NTK, 2.5m
15002LL PLM – Pro Lambda Meter Kit with NTK, 5m
59001 Lambda bung, Mild Steel 18*1.5 Weld in
59002 Lambda bung, Stainless Steel 18*1.5 Weld in
61038 Loom – PLM (Bosch) 2.6m (old style)
61039 Loom – PLM (NTK UEGO) 2.6m (old style)
61040 Loom – PLM (Bosch) 6m (old style)
61041 Loom – PLM (NTK EUGO) 6m (old style)
61103 PLM loom to LSU Adapter
61104 PLM Loom to LSU 4.2 Adapter
61105 PLM Loom to NTK Adapter
61106 PLM common loom (2.6m)
61107 PLM common loom (6m)

Lambda Sensors

What is Wideband and Narrow Band Lambda?

Narrow Band Lambda - Narrow Band Lambda provides an output voltage between .1v and 1.0v DC based on the oxygen differential between the exhaust pipe and the atmosphere. This can give an indication of the air fuel ratio at which the engine is running, however the sensor range is limited to air/fuel ratios of about 14.0:1 (1.0v) and 15.4:1(.1v). At ratios beyond this range the sensor output does not increase or decrease, making it virtually useless for tuning an engine for anything other than steady state cruising.
The advantage of Narrow Band Lambda comes into play while trying to keep emissions in check. The sensor provides a signal to the ECU which basically indicates either rich (output voltage above .5v air fuel less than 14.7) or lean (output voltage below .5v air fuel greater than 14.7) but really does not describe to what degree the mixture is either rich or lean. This fits perfectly with the need for 'perturbation' of today's 3 way catalysts which need excess air to catalyze Hydrocarbon and Carbon Monoxide, and excess fuel with which to reduce Oxides of Nitrogen. Because of this requirement by the catalyst, Narrow Band Lambda Control is constantly varying the air/fuel ratio both slightly above and below 14.7:1 in such a manner that the average air fuel ratio is maintained at 14.7:1. Most engines in use today produce peak power with air fuel ratios in the 12:1 - 13.5:1 range, well below the measuring capability of a Narrow Band Lambda sensor. It is for this reason that Narrow Band Lambda is insufficient for high loads and/or RPM.

Wideband Lambda - Wideband Lambda provides the ECU with a specific definition of the air fuel ratio at which the engine is currently running. Wideband sensors are able to detect air fuel ratios as rich as 10.5:1 and as lean as 18:1 and report the exact Lambda to the ECU. This is done in a number of ways. MoTeC M4 and M48 ECUs use Bosch 4 wire Wideband Lambda sensors to measure Wideband Lambda. MoTeC M400/600/800/880 ECUs use either the Bosch LSU or the NTK UEGO 5 Wire Wideband Lambda Sensor. MoTeC then uses this information to determine the actual Lambda and displays this on the console and/or uses it for Lambda Control if the ECU is set up to do so.

4 Wire Wideband Lambda Sensor - This technology takes advantage of the fact that a 4 Wire Wideband Lambda sensor's voltage output is based not only on the oxygen differential between the exhaust pipe and atmosphere, but is also dependant on the temperature of the sensor itself. Sensor impedance varies with temperature, so a MoTeC ECU measures not only Wideband Lambda Voltage, but also the sensor impedance.

NTK/LSU Wideband Lambda Sensor - This newer technology is used to determine the air fuel ratio of an engine by measuring Lambda sensor output and the current required to hold the sensor voltage output constant. An oxygen sensor produces voltage and a small amount of current as oxygen atoms pass across its substrate from high concentration to low concentration. The greater the flow of oxygen, the greater the voltage produced. This is the case when a rich mixture is encountered. Conversely, when current is applied to an oxygen sensor, oxygen atoms are moved from a low concentration to a high concentration or vice versa depending on the polarity of the current applied. The MoTeC M400/600/880/800 ECUs are capable of measuring this type of sensor input which offers increased speed and accuracy over the older technology 4 wire sensors. M4 and M48 ECUs can leverage the 5 wire technology by connecting a MoTeC PLM - which has a definable analogue voltage output - to the Lambda input on the ECU.

Row 1: Bosch 4 wire, Narrowband,
Row 2: NTK, Bosch LSU

57001	**Lambda sensor wideband, Bosch LSM (4 Wire)** (Technical Drawing X03)
57002	**Lambda sensor, narrow band Ford**
57003	**Lambda sensor wideband NTK UEGO** (Technical Drawing X27)
57004S	**Lambda sensor wideband Bosch LSU** (Technical Drawing X25)
57005	**Lambda sensor Wideband Bosch LSU 4.2**

2.3 ADL specifications

MoTeC SPECIFICATIONS - ADVANCED DASH LOGGER (ADL) MoTeC

GENERAL

- Microprocessor: 32 bit high performance
- Manufacturing Quality Standard: ISO9002
- Field updateable operating system
- Non-volatile FLASH memory for data and operating system
- High RFI immunity
- Rugged aluminium housing (IP-55, NEMA 4)
- 79 pin Autosport connector
- Operating Temperature: -10 to 70° C
- Operating voltage: 7 to 22 VDC
- Operating Current: 0.3 A maximum
- Weight: 385gms (0.85 lbs)
- Size: 180mm x 91mm x 18mm (excluding connector)
- Reverse battery and transient protection
- Warranty: 2 years parts and labour

MEASUREMENT INPUTS

- 28 Analog Inputs (10 standard):
  - 20 Analog Voltage (6 standard)
  - 8 Analog temperature (4 standard)
  - 12 bit resolution, 0 to 15 VDC range
  - Update rate: up to 1000 times/second (maximum 8 channels)
  - Other inputs: up to 500 times/second
- 2 Low voltage analog inputs
  -12 bit resolution, 0 to 1 VDC range (differential)
- 4 Digital Inputs (2 standard)
- 4 Speed Inputs (2 standard)
  Digital and speed:
  - Switch to 0V, logic signal, open collector (Hall Effect), or Magnetic (speed inputs only)
  - State and counting (1MHz)
  - Period (1 microsecond)
  - Pulse width (1 microsecond)
- 4 Switch Inputs (4 standard)
- User definable sensor calibrations

AUXILIARY OUTPUTS

- 8 Digital Outputs (4 standard)
  - Open Collector (drives to the ground) with pullup (10k ohms) to battery positive
  - On/Off or Pulse Width Modulation with variable frequency and duty cycle

AIR FUEL RATIO MEASUREMENT (OPTIONAL)

- 2 High Accuracy Wideband Lambda (Air/Fuel ratio) Inputs
- Resolution: 0.01 Lambda
- Temperature compensated
- Range: 0.75 to 1.5 Lambda
- Accuracy: 1.5% (below 1.05 Lambda)

DATA LOGGING

- Memory: 384Kbyte, 1Mbyte, 2Mbyte, 4Mbyte or 8Mbytes
- Non-volatile FLASH, field upgradeable
- Logging of any Analog, Digital, Serial, CAN bus or calculated channel
- Maximum Logging throughout: 20Kbytes/second
- 2 Burst Logging buffers with pre triggering (4Mbyte and 8Mbyte logging option only)
- Typical Unload Speed: 19 sec/Mbyte, using parallel port of PC to CAN bus RS232 unload rates dependent on baud rate.

CALCULATIONS

- 8 x Timers (0.01s, 0.1s and 1s resolution)
- 8 x 2D and 4 x 3D Tables
- 20 x User Conditions
- Math Functions: Differentiate, Integrate, Absolute, Min/Max
- Lap Timer and Number
- Lap Gain/Loss
- Speed and Distance
- Gear Detection
- Fuel Prediction
- Tell-tales
- Running Min/Max

DISPLAY

- Custom LCD, High Contrast, High Temperature, Reflective
- Backlit LCD display (optional)
- Display any Analog, Digital, Serial, CAN bus or calculated channel
- 3 Display modes
- 70 Segment bar graph:
  -Definable range
  -Programmable setpoint and peak hold point
- 4 Numeric display items
- 13 Digit alpha numeric display area, 1, 2 or 3 channels per line (20 scrollable lines per display mode)
  - Alarm messages, channel display or descriptive text
- Enclosed ADL (without display) (optional)

COMMUNICATION

- Serial RS232 Comms. (1200 baud to 115k baud)
- CAN data link (250Kbit to 1Mbit)
- Telemetry link output (RS232)

HOST SOFTWARE

1. Dash Manager Software
2. Interpreter Analysis Software
3. Telemetry Software (Optional)

Computer Requirements:

- IBM PC compatible running Windows 95/98/ME/XP or NT4.0/2000
- Pentium (Min.) 90MHz, 16Mb RAM

UPGRADES

The *MoTeC* ADL in its base configuration includes:

- 6 Analog Voltage Inputs, 4 Analog Temperature Inputs
- 4 Switch Inputs, 2 Digital Inputs, 2 Speed Inputs
- 4 Auxiliary Outputs
- No memory (384Kbytes minimum recommended)
- RS232 and CAN bus communications support
- Software: Dash Manager and Interpreter
- User's Manual

ADL Upgrades *(field updateable by the user):*

- ***Input and Output Upgrades***

30 Input/Outputs

- 10 Analog Voltage Inputs, 4 Analog Temperature Inputs
- 4 Switch Inputs, 2 Digital Inputs, 4 Speed Inputs
- 2 x Low Voltage Analog Inputs, 4 Auxiliary Outputs

50 Input/Outputs

- 20 Analog Voltage Inputs, 8 Analog Temperature Inputs
- 4 Switch Inputs, 4 Digital Inputs, 4 Speed Inputs
- 2 x Low Voltage Analog Inputs, 8 Auxiliary Outputs

- ***Pro Logging*** - Advanced Analysis Software
  - XY Plots
  - Advanced Math Functions
  - Rainbow Track Mapping
  - Lap Reports
- ***Memory Upgrades***
  - 384Kbyte: - Entry Level Memory
  - 1Mbyte: - 384Kbyte to 1Mbyte Memory
  - 2Mbyte: - 1Mbyte to 2Mbyte Memory
  - 4Mbyte: - 2Mbyte to 4Mbyte Memory } includes burst logging
  - 8Mbyte: - 4Mbyte to 8Mbyte Memory } includes burst logging
- ***Lambda Measurement :*** - 2 Wideband Lambda Inputs
- ***Telemetry:*** - Enables real-time viewing of data via a telemetry link
- ***Remote Logging*** *(requires Telemetry Upgrade)*
  - Allows Remote Logging via a telemetry link or hand held computer

ACCESSORIES

- PC Communications Cable (High Speed CAN)
- Wiring Looms
- Input/ Output Terminal Module
- Lambda (Air/Fuel ratio) Sensors and Kits (see separate data sheet)
- Telemetry Products - GSM mobile phones, radio modems etc.
- Sensors and transducers - a full range of sensors, amplifiers, transducers, lights and buttons are available
- Lap Beacon: Transmitter and Receiver (990 channel)

2.4 Theoretical calculation of excel tool for hydrogen car tuning

An Excel spread sheet was developed to calculate all engine operating conditions and control parameters. The built-in calculations took into account the engine boundary conditions represented by high load and high speed or low load high speed as well as idle condition to ensure that sufficient amount of hydrogen is provided.

In addition, the calculations considered the mass of air and mass of hydrogen required per inlet stroke per cylinder corresponding to individual operating point. Calculation for the percentage of hydrogen volume displacing the volume of air at specific lambda value (equivalent air to fuel ratio) was also carried out. From these calculations, it has been decided that each selected high flow Quantum hydrogen injector should inject fuel at the pressure of 45 PSIG.

In detail, the calculator estimates the cam profile, inlet valve profile, exhaust valve profile, start / end of injection timing, injection duration, lambda value, predicted pressure droop in fuel rail, and the generated torque output etc…corresponding to the whole range of engine speed and load points (throttle position).

To calculate the required engine control parameters and engine performances, the area in white are entered and the results are given in area shaded yellow. The required parameters to be entered are the amount of engine speed and throttle position. The following provided data and assumptions are incorporated into the calculation:

1. The cam advanced profile and mass air flow per induction are calculated and based on the initial information supplied from MoteC and previous intelligent car project[6] as well as associated research work in [65, 66].
2. The injection timing setting is the end of injection as to improve reliability of injector end angle before inlet valve close.
3. Injection duration is calculated based on the provided specification of Quantum high flow injector part number 103738. In addition, inlet vale open duration is estimated so that sufficient injection duration is carried out.

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[6] Intelligent Car Project by David Andrew Butler

4. The desired lambda table is made for the corresponding engine speed and throttle position. These desired values are based on literature review of different resources as well as experiences being developed within the research staffs.
5. The calculations are also incorporated with hydrogen fuel‘s properties.

The sample snapshot with calculation result at an engine speed of 4250 RPM and throttle position at 50% is given in the Figure 1 below.

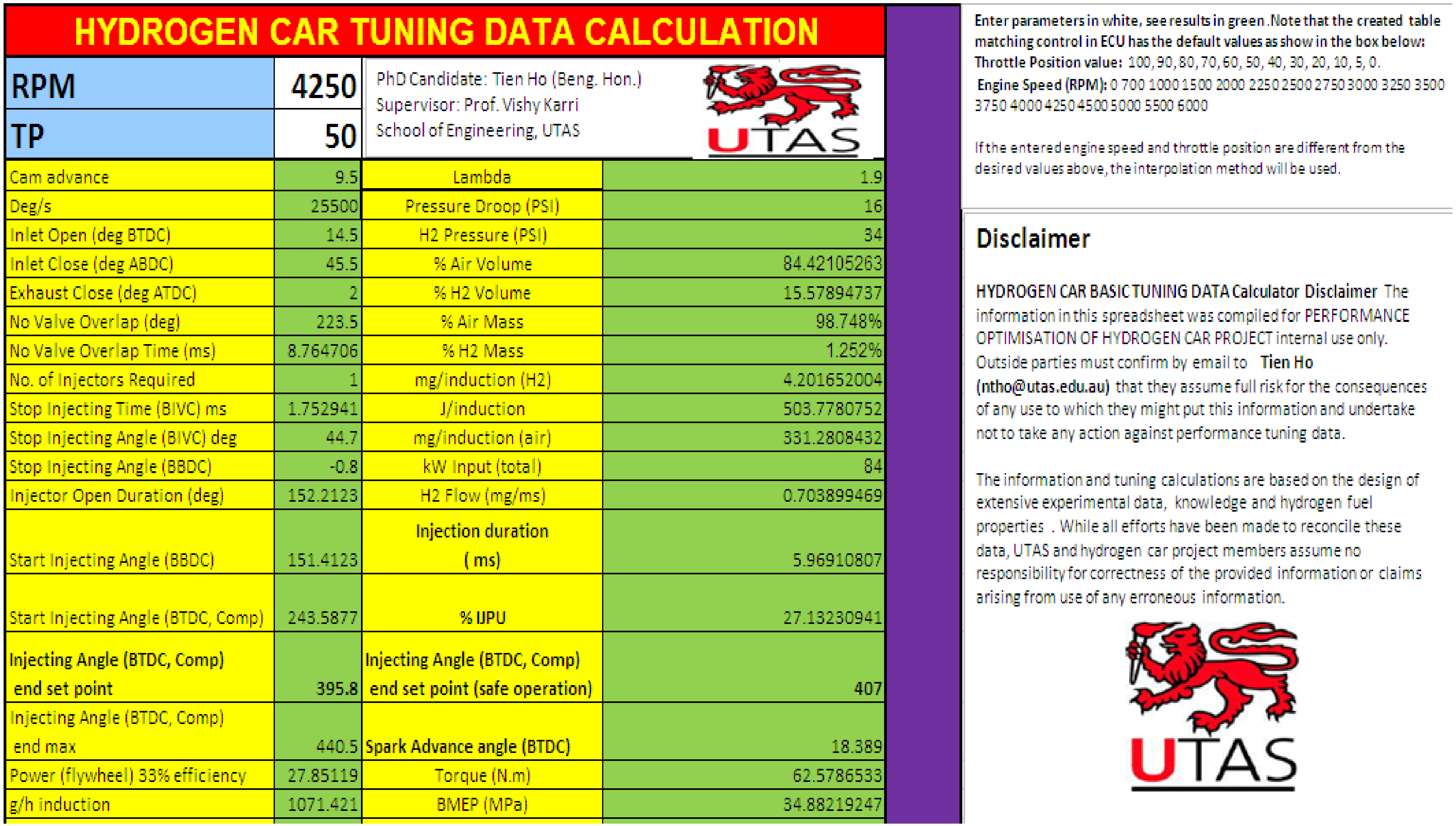


Figure 1 Graphic user interface of hydrogen tuning data tool

Table 1 Properties of hydrogen fuel.

Properties	Hydrogen
Molecular weight	2.016 g/mol
Density at STP (Standard Temperature and Pressure)	0.0838 kg/m^3
Calorific value	119.9 -141.9 MJ/kg
	or 10.05 - 11.89 MJ/m^3
Boiling Temperature	20.3 K
Self ignition temperature	858 K
Ignition limits in air	4%-75% (by volume)
Stoichiometric mixture in air	29.6% (by volume)
Flame temperature in air	2318 K
Diffusion emissivity	34-43%
Specific heat (Cp) at STP	14.89 kJ/(KgK)
Critical point temperature	32.94 K
Critical point pressure	12.84 bar

2.4.1 Estimation of valve timings

2.4.2 Estimation of Cam profile

Initial estimation table of cam profile was provided from MoteC as the basic tuning knowledge that can be incorporated into consideration.

Table 2 Cam advance table

Cam Advance (deg)	RPM											
Throttle %	0	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
100	5	7	9	14	18	17	22	18	9	3	0	0	0
90	5	7	9	14	18	17	22	18	10	3	0	0	0
80	5	7	9	14	18	17	22	18	10	4	0	0	0
70	5	7	9	14	18	17	23	18	11	5	1	0	0
60	5	7	9	14	18	18	24	18	13	5	1	0	0
50	5	7	9	14	18	18	25	18	14	5	1	0	0
40	5	7	9	14	20	21	30	23	15	5	1	0	0
30	5	7	9	16	26	36	40	33	14	17	2	0	0
20	7	8	10	26	32	26	23	19	16	13	7	0	0
10	10	13	16	17	5	3	3	3	8	3	2	0	0
5	8	9.5	11.5	12.5	3.5	1.5	1.5	1.5	4	1.5	1	0	0
0	6	6	7	8	2	0	0	0	0	0	0	0	0

The estimation of valve timings that were included the inlet valve open and inlet valve close as such these two timings were varied according to the information provided from the car's manufacturer (Toyota). The inlet valve open was based on cam profile plus 5 degree crank angle (CA) and has to be within the range from 5^{o} to 48^{o} CA before top dead center (BTDC). The inlet valve close would be varied between the ranges of 55^{o} to 12^{o} CA after bottom dead center (ABDC) as depicted in valve timing diagram below.

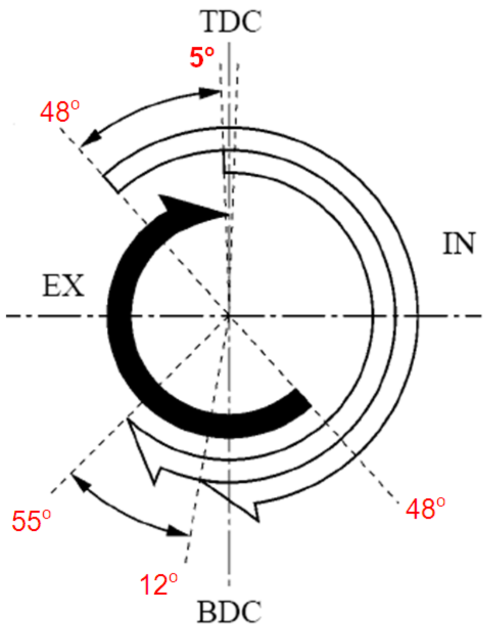


Figure: Valve timing diagram

From the diagram above, the duration of inlet valve opening time is 240 degree CA as calculated below:

$5^{o}+180^{o}+55^{o}=240^{o}$ CA or $48^{o}+180^{o}+12^{o}=240^{o}$ CA

And the duration of exhaust valve opening time is 230 degree CA as calculated below:

$48^{o}+180^{o}+2^{o}=230^{o}$ CA

2.4.3 Estimation of the air mass flow

The estimation of mass air flow was based on previous confirmation of intelligent car project [3] as well as basic tuning measurement taken from gasoline engine [2]. Table below shows the estimation of the mass air flow per induction.

Table 3 Air mass flow per induction table

mg/induction (air)	RPM												
Effective Throttle %	0	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
100	238	316	325	343	343	359	364	361	384	381	379	390	396
90	253	307	311	322	330	344	342	346	359	376	375	382	384
80	254	299	308	316	328	336	330	330	349	368	366	371	371
70	243	290	306	310	321	320	317	314	331	344	350	352	350
60	243	296	307	300	305	308	302	293	308	314	313	315	309
50	258	294	301	285	294	287	268	264	269	272	260	260	244
40	256	280	287	269	267	255	227	217	208	202	186	183	183
30	242	276	291	233	224	195	166	155	132	121	107	107	107
20	221	242	258	191	149	125	99	91	74	66	65	65	65
10	161	186	193	102	85	73	57	47	41	50	52	52	52
5	112	112	112	76	53	53	42	38	33	34	34	34	34
0	86	45	50	45	45	42	35	32	31	31	31	31	31

2.4.4 Calculation of necessary parameters to be controlled in ECU

2.4.4.1 Estimation of fuel requirement

The estimation of equivalent air to fuel ratio at the desired lambda value was carried out based on the knowledge of previous experiments of hydrogen car project. The given lambda table as shown below.

Table 4 Initial desired Lambda table

Initial desired Lambda	RPM												
Effective Throttle %	0	700	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
100	1.10	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.45	1.40	1.35	1.30
90	1.36	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
80	1.46	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
70	1.48	1.70	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.80	1.80	1.80	1.80
60	1.60	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.85	1.85	1.85	1.85
50	1.94	1.90	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.90	1.90	1.90	1.90
40	2.10	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.95	1.95	1.95	1.95
30	2.20	2.00	1.95	1.95	1.95	1.95	1.95	1.95	1.95	2.00	2.00	2.00	2.00
20	2.55	2.00	2.00	2.00	2.00	2.19	2.00	2.10	2.00	2.10	2.10	2.10	2.10
10	2.13	2.00	1.90	2.00	2.00	2.20	2.10	2.30	2.30	5.00	5.00	5.00	5.00
5	1.02	1.90	1.80	2.47	2.20	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
0	1.00	1.00	2.30	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

The flow rate together with the knowledge of engine speed allows the calculation of air to fuel ratio entering each combustion chamber of hydrogen engine. The dedicated calculation is shown below:

Volume per intake stroke: 450 cm^3 = 4.5×10^{-4} m^3

Intake stroke per revolution: $\frac{240}{360}=0.67$

Revolution rate or engine speed = N (rpm)

Therefore the air fuel flow rate

$$\frac{N\times0.67\times4.5\times10^{-4}}{60} m^3/s = N\times5.025\times10^{-6} m^3/s = N\times5.025\times10^{-3} l/s \qquad (1)$$

And % volume hydrogen in air fuel mixture: $\frac{\text{volumetric flow rate of hydrogen}}{5.025}\times100$ (2)

Also equivalent ratio

$$\theta = \frac{\text{\% hydrogen in air fuel mixture}}{\text{\% hydrogen in stoichiometric air fuel mixture}} \qquad (3)$$

Where % hydrogen in stoichiometric air fuel mixture is 29.6% (as shown in table of hydrogen properties).

Therefore from (2) and (3), volumetric flow rate of hydrogen (V_{H2}) at an equivalent ratio θ and engine speed N (rpm) is calculated as:

$$V_{H2} = \frac{5.025\times10^{-4}\times N\times29.6\times\theta}{100} = 1.4874\times10^{-6}\times N\times\theta \ \ m^3/s$$

Furthermore, hydrogen density

$$\rho = 0.0838\times\frac{298}{T(^{o}k)}\times\frac{P(kPa)}{101.3}$$

Where T is the temperature in Kelvin and P is the pressure in kPa.

Finally, the mass flow rate of hydrogen $= \rho\times\theta\times N\times1.4874\times10^{-6}\,Kg/s$

For instance, an engine speed of 3000 rpm with an equivalent ratio of 0.5 at a pressure of 310.264 kPa (45 PSI) and temperature of 293.15 ^{0}K (20 ^{0}C)

$$0.0838\times\frac{298}{293.15}\times\frac{310.264}{101.3}\times0.5\times3000\times1.4874\times10^{-6} \approx 0.5825\times10^{-3}\,kg/s = 0.5825\ g/s$$

These theoretical calculations were utilised for selection of hydrogen fuel injector which have the suitable injection flow rate for the converted hydrogen engine in this project.

The flow rate specifications under dedicated fuel pressure of the chosen Quantum high flow injector part number 103738 are shown below.

Table 5 Hydrogen flow (mg/pulse)

Inlet Pressure	Period (ms)									
(psig)	2.5	3.0	4.0	6.0	8.0	12.0	14.0	16.0	17.0	18.0
20	1.51	1.80	2.29	3.23	4.19	6.05	6.93	7.79	8.61	9.08
40	2.07	2.48	3.27	4.80	6.29	9.18	10.56	12.04	13.63	14.59
60	2.47	3.07	4.15	6.19	8.16	12.24	14.14	16.06	18.22	19.51
80	2.73	3.49	4.82	7.34	9.44	14.94	17.35	19.69	22.11	23.27

2.4.4.2 Injection duration

The injection duration was calculated based on the desired Lambda value and mass air flow per inlet stroke of each cylinder at dedicated engine speed and load.

It has been desired that the hydrogen injection duration should be after exhaust valve close (as shown in Figure 2) and before inlet valve close to guarantee that backfire free of engine operation can be achieved.

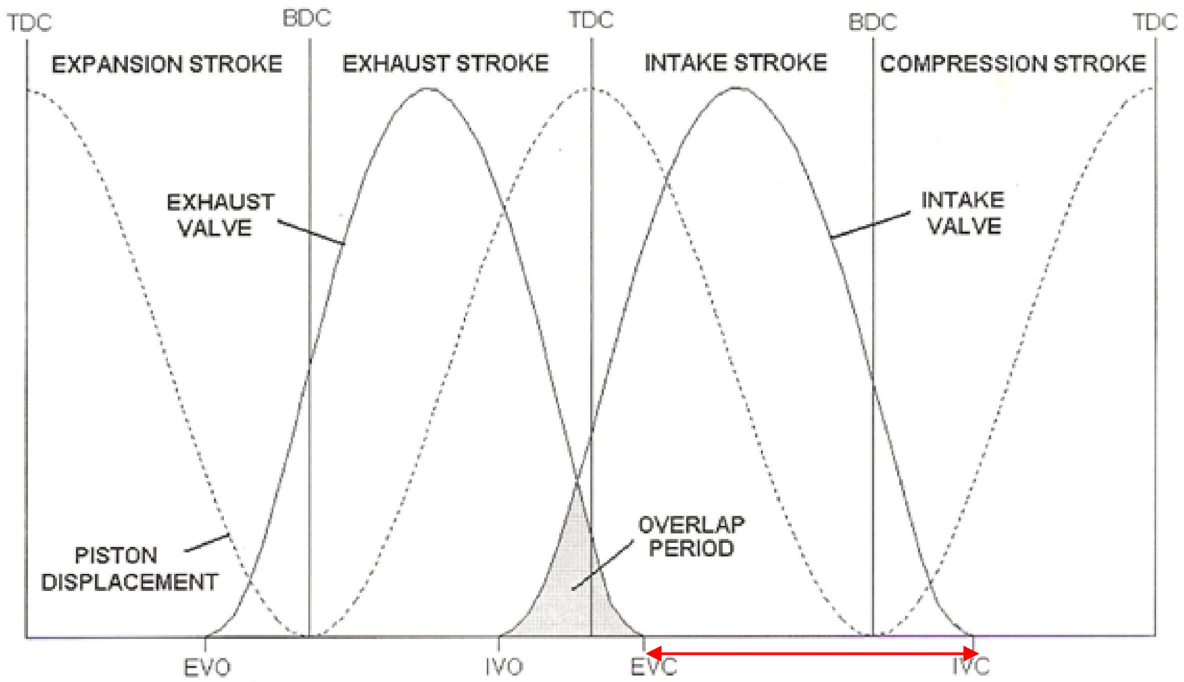


Figure 2 Hydrogen injection duration profile.

Therefore, the injection start angle should be after 2^{o} CA ATDC. The injection duration are estimated to be within the range of 190^{o} CA and 233^{o} CA as shown below:

When the inlet valve closes at 12^{o} ABDC:

$$-2+180+12 = 190^{o}\text{ CA.}$$

When the inlet valve closes at 55^{o} ABDC:

$$-2+180+55 = 233^{o}\text{ CA.}$$

2.4.4.3 End of injection angle calculation

The Ref and Sync sensors were utilised to define the crank index position of the converted hydrogen car. The result has shown that crank index position was 575^{o} CA (end of compression stroke at top dead center). As such, the largest value of end of injection setting is 450^{o} CA as calculate below:

Compression stroke end at 575^{o} CA

Compression stroke duration is 180^{o} CA

Minimum inlet valve closes at 12^{o} ABDC and maximum inlet valve closes at 55^{o} ABDC

Therefore, the end of injection angle could be in the range between 407^{o} CA and 450^{o} CA as calculated below:

$$575 - 180 + 12 = 407^{o}\text{ CA}$$

$$575 - 180 + 55 = 450^{o}\text{ CA}$$

However, it has been decided that the calculation tool considers setting of the end of injection angle 10% of time before inlet valve close. This is to ensure that more conservative results in calculation for achieving backfire free engine operation in the first attempt of tuning hydrogen car.

2.4.4.4 Estimation for ignition timing

Generally, the rule of thump for lean best torque setting was based on the previous experiments of hydrogen engines in literature review section. The setting for ignition timing as shown in table below:

Table 6 Lean best torque ignition advance setting for hydrogen car[4]

Equivalent Ratio (θ)	Lambda (λ)	Ignition Advance (^{o} BTDC)
0.45	2.22	24
0.60	1.67	14
0.85	1.18	7
1.00	1.00	2

The ignition advance tuning will be done on a dynamometer so that more accurate control of hydrogen engine at particular map site can be achieved.

2.4.5 Calculation of hydrogen engine performance parameters

2.4.5.1 Torque, power and brake mean effective pressure calculation

Theoretically, the power supplied by fuel (KW input) is calculated as below:

$$\text{Power supplied by fuel (kW)} = \text{lower calorific value (kJ/kg)} * \text{hydrogen mass flow rate (kg/sec)}$$

Where lower calorific value of hydrogen: 119,900 kJ/kg

The assumptions have been made with power at flywheel is about 33% efficiency comparing with the power supplied by and power at wheel is about 74% of power at flywheel. Therefore, the torque generated is calculated as:

$$\text{Torque (N.m)} = \frac{1000 \times \text{power at flywheel (kW)}}{\frac{\text{enginespeed (RPM)}}{60} \times 2\pi}$$

$$\text{Power at flywheel (kW)} = \frac{\text{Power at wheel (kW)}}{0.74}$$

The brake mean effective pressure (BMEP) of an engine is equivalent to the engine's torque divided by its displacement as shown below:

$$\text{BMEP (MPa)} = \frac{\text{Torque (N.m)}}{1.794}$$

2.4.5.2 Fuel consumption

The brake specific fuel consumption is calculated as below:

$$\text{BSFC (g/kWh)} = \frac{\text{hydrogen mass flow rate (g/h)}}{\text{Power supplied by fuel (kW)}}$$

References

1. Lim, J., *Development of a hydrogen car and emissions modelling using artificial intelligence tools*, in *School of Engineering*. 2007, University of Tasmania: Hobart, Tasmania, Australia.

2. Barrett, D.S.T., *Study of the Performance of a Four Cylinder Hydrogen-Fuelled Internal Combustion Engine*, in *School of Engineering* March 2007, University of Tasmania: Hobart, Australia.

3. Butler, D.A., *Enhancing Automotive Stability Control with Artificial Neural Networks*, in *School of Engineering*. 2006, University of Tasmania: Hobart.

4. Peavey, M.A., *Fuel From Water Energy Independence With Hydrogen*. Eleventh ed. 2003, Louisville, KY 40201, USA: Merit Inc. .

5. Laning, R., *Hydrogen as a fuel in an internal combustion engine*, in *School of Engineering*. October 2002, University of Tasmania: Hobart.

2.5 The "foptcon" single objective optimisation algorithm[7]

foptcon is a single-objective optimization subject to constraints. This function uses the MATLAB® fmincon algorithm from the Optimization Toolbox™ product.

fmincon Algorithms

fmincon has four algorithm options:

- 'interior-point'
- 'sqp'
- 'active-set'
- 'trust-region-reflective' (default)

Use optimset to set the Algorithm option at the command line.

Recommendations

- Use the 'interior-point' algorithm first.

  For help if the minimization fails, see "When the Solver Fails" on page 4-3 or "When the Solver Might Have Succeeded" on page 4-14.
- To run an optimization again to obtain more speed on small- to medium-sized problems, try 'sqp' next, and 'active-set' last.
- Use 'trust-region-reflective' when applicable. Your problem must have: objective function includes gradient, only bounds, or only linear equality constraints (but not both).

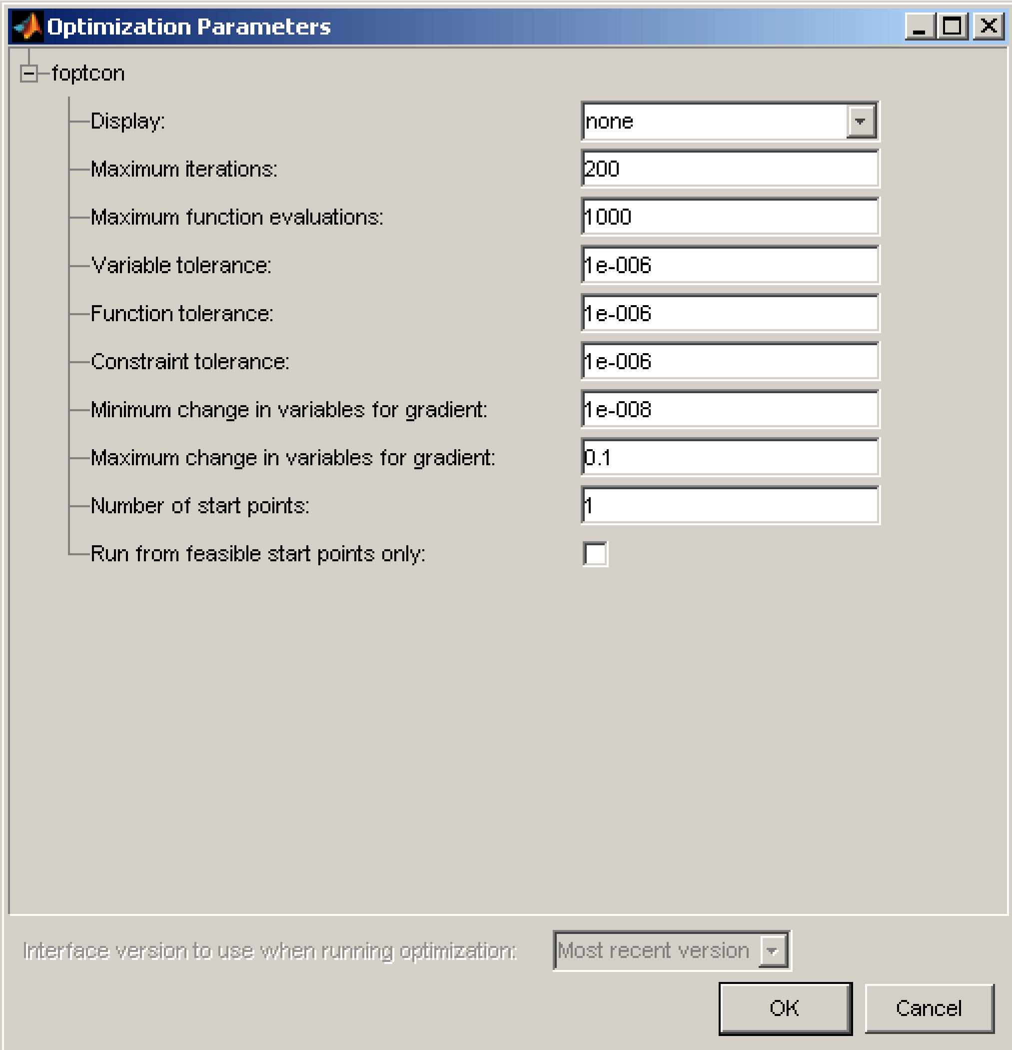
[7] The "foptcon" single objective optimisation algorithm is made available in the MBC toolbox

Reasoning Behind the Recommendations.

- `'interior-point'` handles large, sparse problems, as well as small dense problems. The algorithm satisfies bounds at all iterations, and can recover from `NaN` or `Inf` results. It is a large-scale algorithm; see "Large-Scale vs. Medium-Scale Algorithms" on page 2-35. The algorithm can use special techniques for large-scale problems. For details, see "Interior-Point Algorithm" on page 11-56.
- `'sqp'` satisfies bounds at all iterations. The algorithm can recover from `NaN` or `Inf` results. It is not a large-scale algorithm; see "Large-Scale vs. Medium-Scale Algorithms" on page 2-35.
- `'active-set'` can take large steps, which adds speed. The algorithm is effective on some problems with nonsmooth constraints. It is not a large-scale algorithm; see "Large-Scale vs. Medium-Scale Algorithms" on page 2-35.
- `'trust-region-reflective'` requires you to provide a gradient, and allows only bounds or linear equality constraints, but not both. Within these limitations, the algorithm handles both large sparse problems and small dense problems efficiently. It is a large-scale algorithm; see "Large-Scale vs. Medium-Scale Algorithms" on page 2-35. The algorithm can use special techniques to save memory usage, such as a Hessian multiply function. For details, see "Trust-Region-Reflective Algorithm" on page 11-53.
  - `'trust-region-reflective'` is the default algorithm for historical reasons. It is effective when applicable, but it has many restrictions, so is not always applicable.

foptcon Optimization Parameters

The `foptcon` optimization algorithm in CAGE uses the MATLAB® `fmincon` algorithm from the Optimization Toolbox™ product. `foptcon` wraps up the `fmincon` function so that you can use the function for maximizing as well as minimizing. For more information, see the `fmincon` reference page in the Optimization Toolbox documentation, fmincon.



- **Display** — choose `none`, `iter`, or `final`. This setting determines the level of diagnostic information displayed in the MATLAB workspace.
  - `none` — No information is displayed.
  - `iter` — Displays statistical information every iteration.
  - `final` — Displays statistical information at the end of the optimization.
- **Maximum iterations** — Choose a positive integer.

  Maximum number of iterations allowed
- **Maximum function evaluations** — Choose a positive integer.

  Maximum number of function evaluations allowed

- **Variable tolerance** — Choose a positive scalar value.

  Termination tolerance on the free variables
- **Function tolerance** — Choose a positive scalar value.

  Termination tolerance on the function value
- **Constraint tolerance** — Choose a positive scalar value.

  Termination tolerance on the constraint violation
- **Minimum/maximum change in variables for gradient**

  Choose a positive scalar to control the input step size that is taken when gradients are being calculated. The default settings should work for the majority of problems.
- **Number of start points** — Choose a positive integer, N. (N-1) start points per run are generated in addition to the starting value specified in the Input Variable Values pane.

  The optimization runs from each of the N start points (possibly subject to feasibility, see **Run from feasible start points only** option) and the best solution is chosen.

  The N-1 extra start points are generated as follows:

  a Generate a 10000 point Halton set design, D, over the free variables.

  b Evaluate the objectives and constraints over D.

  c Return the N-1 feasible points with the lowest objective value.

  If there are not N-1 feasible points, fill the remaining starting values with the points with the lowest maximum constraint violation.

Note For point optimization problems, it is strongly recommended that you set **Number of start points** to either 1 or 2.

- **Run from feasible start points only** — Select this option to terminate all runs that start with an initial value that does not satisfy the constraints. If this condition is not met this is reported in `Output message`, in the **Solution Information** pane of the Optimization Output view.

- **Interface version** — This option is only enabled when a user-defined optimization script does not specify a version to use. Some existing user-defined optimization scripts may require setting the interface version as 2 or 3, according to the toolbox version. Version 3 is preferable, but may not work with all old scripts. See `setRunInterfaceVersion` for details.

2.6 Fuzzy expert system to estimate ignition timing of hydrogen car

FUZZY EXPERT SYSTEM TO ESTIMATE IGNITION TIMING FOR TUNING OF A HYDROGEN CAR

By

HO NHUT TIEN

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School of Engineering, University of Tasmania

1. INTRODUCTION[8]

1.1 General introduction to Fuzzy expert system

1.1.1 What is Fuzzy Logic?

Fuzzy Logic is applied to fuzzy sets where membership in a fuzzy set is a probability, not necessarily 0 or 1. Non-Fuzzy Logic manipulates outcomes that are either true or false. Fuzzy Logic needs to be able to manipulate degrees of "maybe" in addition to true and false. FL (Fuzzy Logic) is a way of dealing with uncertain information and variables that do not permit simple yes/no categorisations.

Fuzzy Logic provides an approach to approximate reasoning in which the rules of inference are approximate rather than exact. Fuzzy Logic is useful in manipulating information that is incomplete, imprecise, or unreliable.

Also called Fuzzy Set Theory extends the simple Boolean operators, can express implication, and is used extensively in Artificial Intelligence (AI) programs. Fuzzy Logic allows computers to work more easily with phrases such as "fairly," "rarely," or "almost." It also allows computers to use more than just true or false.

What is a fuzzy expert System?

A fuzzy expert system is an expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data. The rules in a fuzzy expert system are usually of a form similar to the following:

if x is low and y is high then z = medium

Where x and y are input variables (names for the known data values),

z is an output variable (a name for a data value to be computed),

low is a membership function (fuzzy subset) defined on x,

high is a membership function defined on y, and

medium is a membership function defined on z.

---

[8] This section is mainly referenced from:

1. Negnevitsky, M., *Artificial intelligence: a guide to intelligent systems*. 2001: Harlow, Essex: Addison Wesley, 2001.
2. MATLAB Fuzzy toolbox user guide.
3. Tien Ho, Justin Suwart "Fuzzy expert system for customer profiling", Hobart, Tasmania 2005.

The antecedent (the rule's premise) describes to what degree the rule applies, while the conclusion (the rule's consequent) assigns a membership function to each of one or more output variables.
Most tools for working with fuzzy expert systems allow more than one conclusion per rule. The set of rules in a fuzzy expert system is known as the rule-base or knowledge base.

1.1.3 How is Fuzzy Logic different from conventional control methods?

Fuzzy Logic incorporates a simple, rule-based:
IF X AND Y THEN Z
This approach is used to solve control problem rather than attempting to model a system mathematically.
The Fuzzy Logic model is empirically based, relying on an operator's experience rather than their technical understanding of the system. Therefore, these terms are imprecise and yet very descriptive of what must actually happen. Consider what you do in the shower if the temperature is too cold: you will make the water comfortable very quickly with little trouble. Fuzzy Logic is capable of mimicking this type of behavior but at very high rate.

1.1.4 How Does Fuzzy Logic Work?

Fuzzy Logic requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them.
Generally, Fuzzy Logic is so forgiving that the system will probably work the first time without any tweaking.

1.1.5 When Not to Use Fuzzy Logic

Fuzzy logic is not a cure-all. When should we not use fuzzy logic? Fuzzy Logic is a convenient way to map an input space to an output space. If we find it’s not convenient, try something else. If a simpler solution already exists, use it.
Fuzzy logic is the codification of common sense – use common sense when we implement it and we will probably make the right decision. Many controllers, for example, do a fine job without using fuzzy logic. However, if we take the time to become familiar with fuzzy logic, we’ll see it

can be a very powerful tool for dealing quickly and efficiently with imprecision and non-linearity problem.

1.1.6 What is the Fuzzy Logic Toolbox?

The Fuzzy Logic Toolbox is a collection of functions built on the MATLAB® numeric-computing environment. It provides tools to create and edit fuzzy inference systems within the framework of MATLAB, or to integrate fuzzy systems into simulations with Simulink®, or even build stand-alone C programs that call on fuzzy systems.

This toolbox relies heavily on graphical user interface (GUI) tools to help accomplish the work, although it is possible work entirely from the command line.

The toolbox provides three categories of tools:

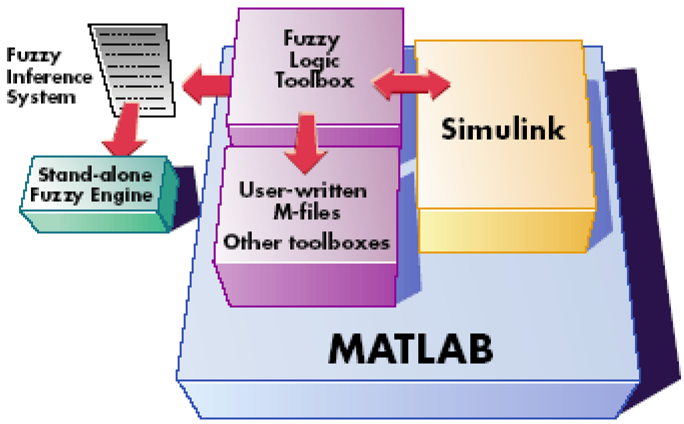
- Command line functions,
- Graphical interactive tools,
- Simulink blocks and examples

The first category of tools is made up of functions that you can call from the command line or from your own applications. Many of these functions are MATLAB M-files, series of MATLAB statements that implement specialized fuzzy logic algorithms.

Secondly, the toolbox provides a number of interactive tools that let you access many of the functions through a GUI. Together, the GUI- based tools provide an environment for fuzzy inference system design, analysis, and implementation.

The third category of tools is a set of blocks for use with the Simulink simulation software. These are specifically designed for high-speed fuzzy logic inference in the Simulink environment.

1.1.7 What Can the Fuzzy Logic Toolbox Do?



The Fuzzy Logic Toolbox allows us to do several things, but the most important thing it can do is create and edit fuzzy inference systems. We can create these systems using graphical tools or command-line functions, or we can generate them automatically using either clustering or adaptive neuro-fuzzy techniques.

The toolbox also makes it possible to run a stand-alone C program directly, without the need for Simulink. A stand-alone Fuzzy Inference Engine that reads the fuzzy systems saved from a MATLAB session makes this possible.

1.1.8 Summary

Fuzzy Logic was conceived as a better method for sorting and handling data but has proven to be an excellent choice for many control system applications since it mimics human control logic. It can be built into anything from small, hand-held products to large computerized process control systems.

Fuzzy Logic uses an imprecise but very descriptive language to deal with input data more like a human operator. It is very robust and forgiving of operator and data input and often works when first implemented with little or no tuning.

1.2 Research Objective

The aim of this research work is to develop a fuzzy expert system to estimate ignition timing of a converted hydrogen car. The system is to be designed so that a tuner can use it as a basic decision when perform basic tuning on the hydrogen car. To make direct decision more efficient, the system is desired to target tuning situations which are more likely to happen in realistic engine operating conditions.

For this research work, six measures can be used to estimate a spark advance angle (degree before top death center) of the hydrogen car including: engine speed (RPM); percentage throttle position (%TP); manifold air pressure (MAP) (kPa); engine power (pow) (kW); hydrogen fuel absolute pulse width (FAPW) (ms); and lambda (La). Figure 1 below depicts the developed fuzzy expert system user interface.

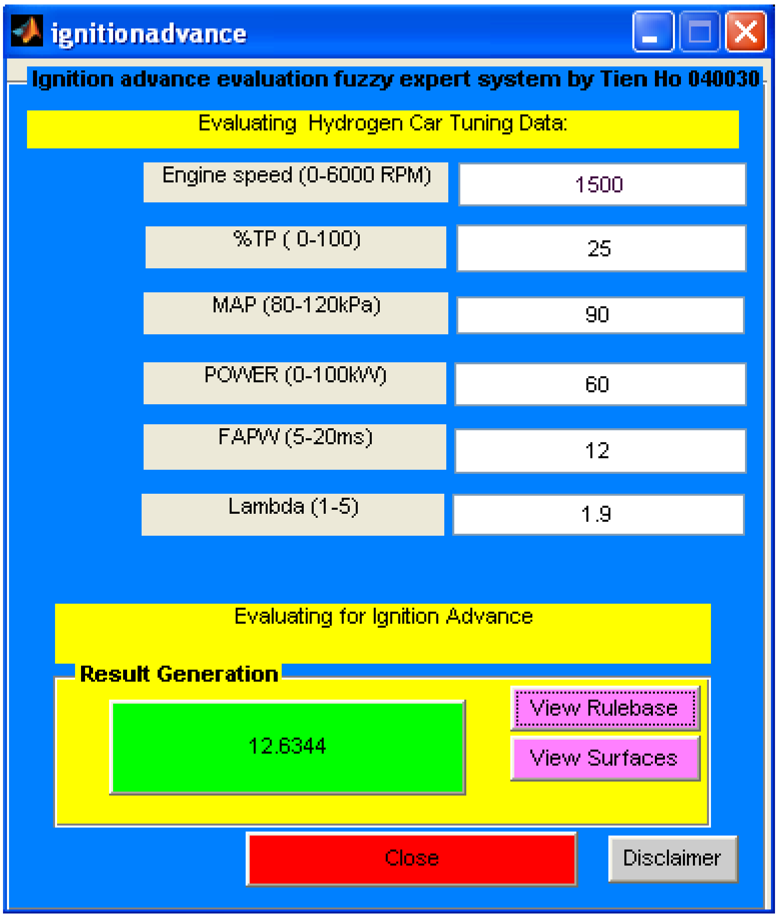


Figure 3 Developed fuzzy expert system user interface

The developed fuzzy expert system is aimed to evaluate all aforementioned parameters inputs and determine the degree before top death center which a spark angle should be tuned.

2. Description of the developed fuzzy expert system

There are several steps that were involved in creating the graphic user interface (GUI) so that it operated correctly with the MATLAB ".fis" files.

Initially, it was important to set up the rules to be used in the fuzzy expert system. This meant creating all the membership functions, and entering all values and ranges that are obtained from the practical tuning of hydrogen car together with tuning experiences. There are 136 rules in the created expert system. They are listed below:

1. If (rpm is low) and (tp is high) and (MAP is medium) and (pow is low) and (FAPW is low_medium) and (La is low) then (IA is low) (1)
2. If (rpm is low) and (tp is high) and (MAP is medium) and (pow is low) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
3. If (rpm is low) and (tp is high) and (MAP is medium) and (pow is low) and (FAPW is low_medium) and (La is medium_low) then (IA is low) (1)
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69. If (rpm is medium_high) and (tp is low) and (MAP is medium_high) and (pow is low) and (FAPW is low) and (La is low) then (IA is low) (1)
70. If (rpm is medium) and (tp is low) and (MAP is low) and (pow is low) and (FAPW is low) and (La is low) then (IA is low) (1)
71. If (rpm is medium) and (tp is low) and (MAP is low) and (pow is low) and (FAPW is low) and (La is low) then (IA is low-medium) (1)

72. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
73. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_high) then (IA is low-medium) (1)
74. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_low) then (IA is low) (1)
75. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
76. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
77. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
78. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is medium) (1)
79. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is medium-high) (1)
80. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is low) (1)
81. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
82. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is medium) (1)
83. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is low-medium) (1)
84. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is medium_high) and (La is low) then (IA is low-medium) (1)
85. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is low-medium) (1)
86. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
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88. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_high) then (IA is medium) (1)
89. If (rpm is medium_high) and (tp is low-medium) and (MAP is medium) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_high) then (IA is medium) (1)

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92. If (rpm is low) and (tp is low-medium) and (MAP is medium_high) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
93. If (rpm is low) and (tp is low-medium) and (MAP is medium_high) and (pow is low) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
94. If (rpm is low) and (tp is medium-high) and (MAP is medium_high) and (pow is low) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
95. If (rpm is low) and (tp is high) and (MAP is medium_high) and (pow is low) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
96. If (rpm is medium) and (tp is high) and (MAP is medium_high) and (pow is low) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
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98. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is low-medium) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
99. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
100. If (rpm is medium) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
101. If (rpm is medium) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is medium) (1)
102. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is medium) (1)
103. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
104. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is low) then (IA is low) (1)
105. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is low) then (IA is low-medium) (1)
106. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is medium_low) then (IA is low-medium) (1)

107. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is medium_low) then (IA is low) (1)
108. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is medium_high) then (IA is low) (1)
109. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low) and (La is medium_high) then (IA is low-medium) (1)
110. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
111. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
112. If (rpm is low) and (tp is medium-high) and (MAP is low) and (pow is low-medium) and (FAPW is low_medium) and (La is low) then (IA is low) (1)
113. If (rpm is low) and (tp is medium-high) and (MAP is medium) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
114. If (rpm is low) and (tp is medium-high) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
115. If (rpm is low) and (tp is high) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is low-medium) (1)
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118. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)
119. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
120. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is low_medium) and (La is low) then (IA is medium) (1)
121. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is low_medium) and (La is medium_low) then (IA is medium) (1)
122. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is low-medium) and (FAPW is low_medium) and (La is medium_low) then (IA is medium) (1)
123. If (rpm is medium_high) and (tp is high) and (MAP is medium) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is low-medium) (1)
124. If (rpm is medium_high) and (tp is high) and (MAP is medium) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is medium) (1)

125. If (rpm is medium_high) and (tp is high) and (MAP is medium) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is medium) (1)
126. If (rpm is medium_high) and (tp is high) and (MAP is medium) and (pow is medium-high) and (FAPW is high) and (La is medium_low) then (IA is medium) (1)
127. If (rpm is medium_high) and (tp is high) and (MAP is medium) and (pow is medium-high) and (FAPW is high) and (La is medium_low) then (IA is medium) (1)
128. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is high) and (La is medium_low) then (IA is medium) (1)
129. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is low_medium) and (La is low) then (IA is medium) (1)
130. If (rpm is medium_high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is low_medium) and (La is low) then (IA is low-medium) (1)
131. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is medium) (1)
132. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is medium) (1)
133. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is low) then (IA is low-medium) (1)
134. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is high) and (La is low) then (IA is low-medium) (1)
135. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is high) and (La is low) then (IA is medium) (1)
136. If (rpm is high) and (tp is high) and (MAP is medium_high) and (pow is medium-high) and (FAPW is medium_high) and (La is medium_low) then (IA is low-medium) (1)

The dedicated case of rule viewer for the developed expert system is shown in figure below.

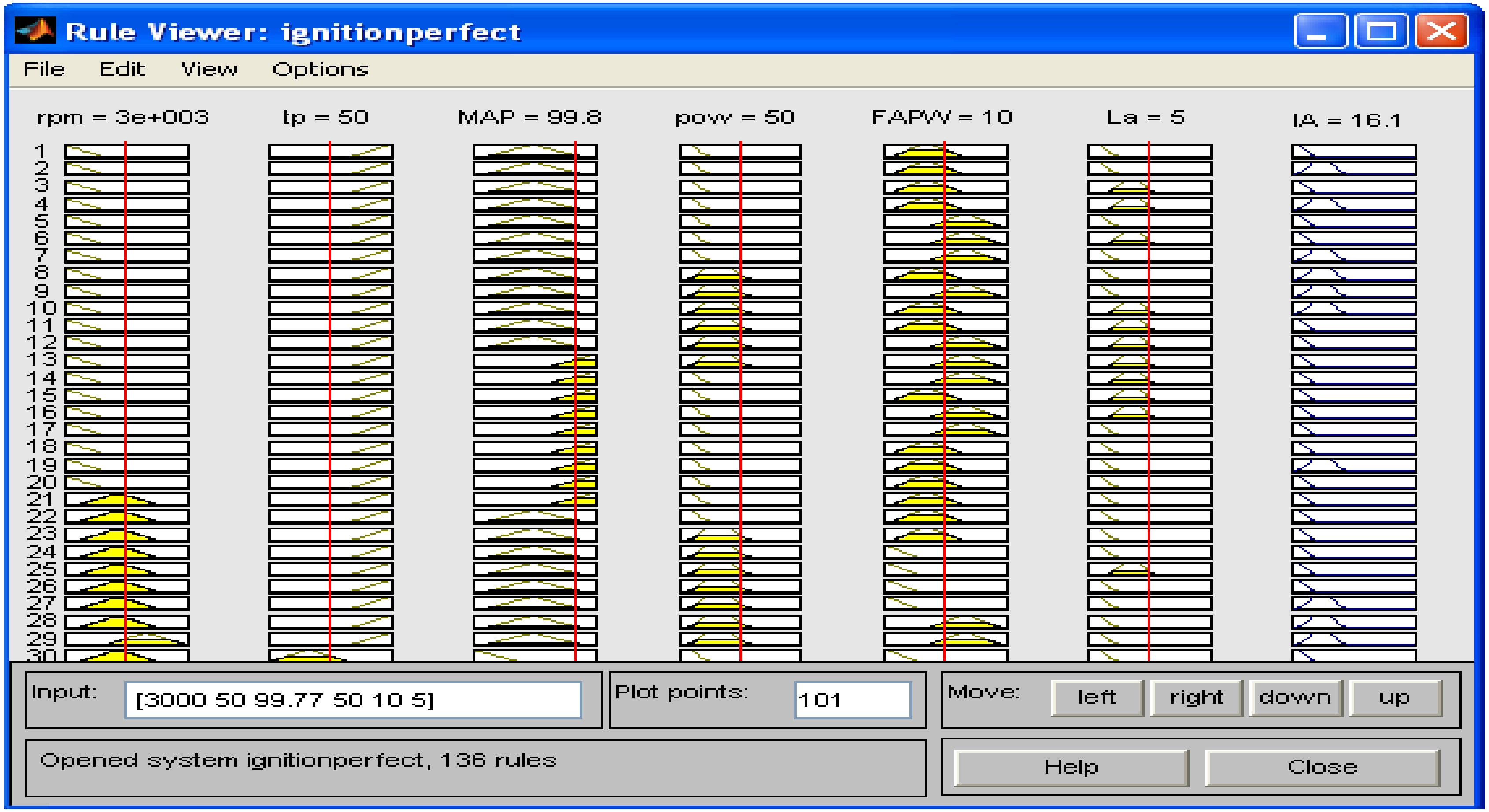


Figure 4 Rule Viewer of developed fuzzy expert system

When these rules were being entered, it was important to consider the range that should be used, i.e. normalized or membership function specialized. It was also necessary to consider the shape of the membership function, i.e. triangular or trapezoidal, etc. Figure 5 shows different desired levels of each membership function and figure 4 depicted a dedicated membership function for engine speed at medium level.

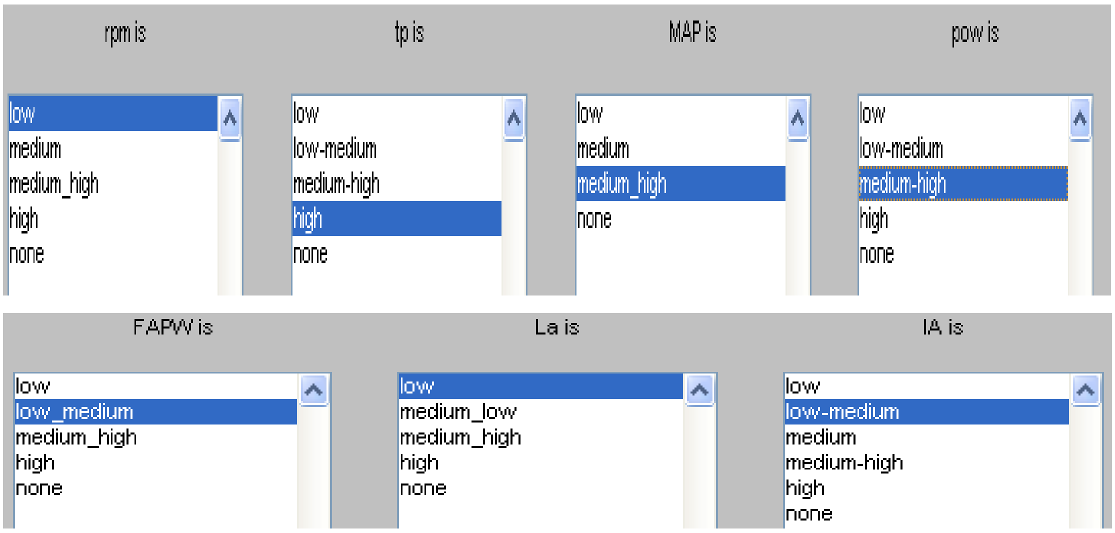


Figure 5 Different desired level of each membership function

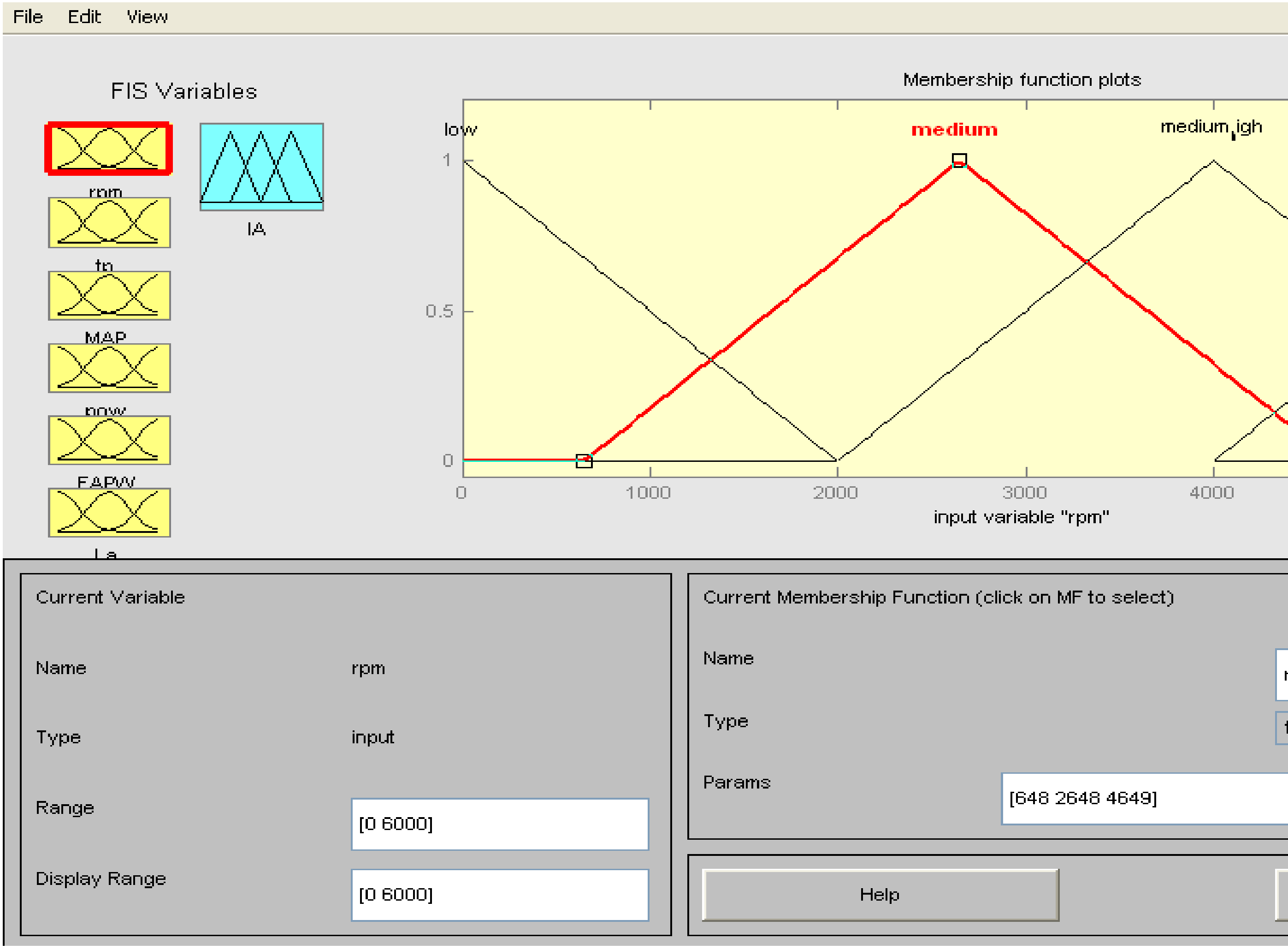
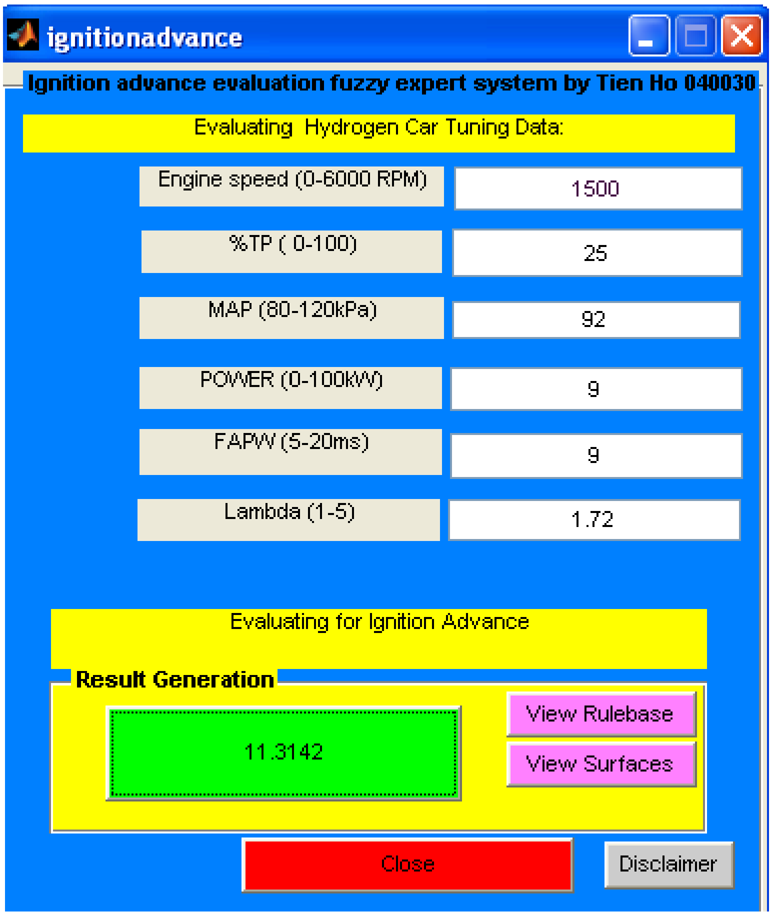


Figure 6 Engine speed membership function at medium level

For more information about the range of each membership function, please direct to the ignition advance program in the attached CD.

3. Examples

Assume that it is required to assess the degree before top death center which a tuner needs to enter into hydrogen car's engine control unit (ECU) at particular engine operating condition as shown in figure below.



The output that is evaluated from the fuzzy expert system is: 11.3142

This ignition advance angle was programmed into the hydrogen car ECU and the tuning result on dynamometer was proved that minimum ignition advance for maximum brake torque was achieved at 12.5 degree BTDC.

4. User's Guide

The fuzzy expert system program has been developed with the user in mind. Simple entry of hydrogen engine operating conditions makes the expert system to estimate ignition advance tuning information. Whenever there are exception catchers, error dialog, bad data storage safety-guards, and simple explanations make it possible to use this expert system successfully in the first time.

Simple information entry about hydrogen engine operating condition is the key to this expert system. The correct information is needed to enter into the appropriate field. If the data is not in the correct range or not a numeric value (i.e. character), a helpful dialog box will be displayed, showing the user that there is an error. A dedicated error figure is shown below.

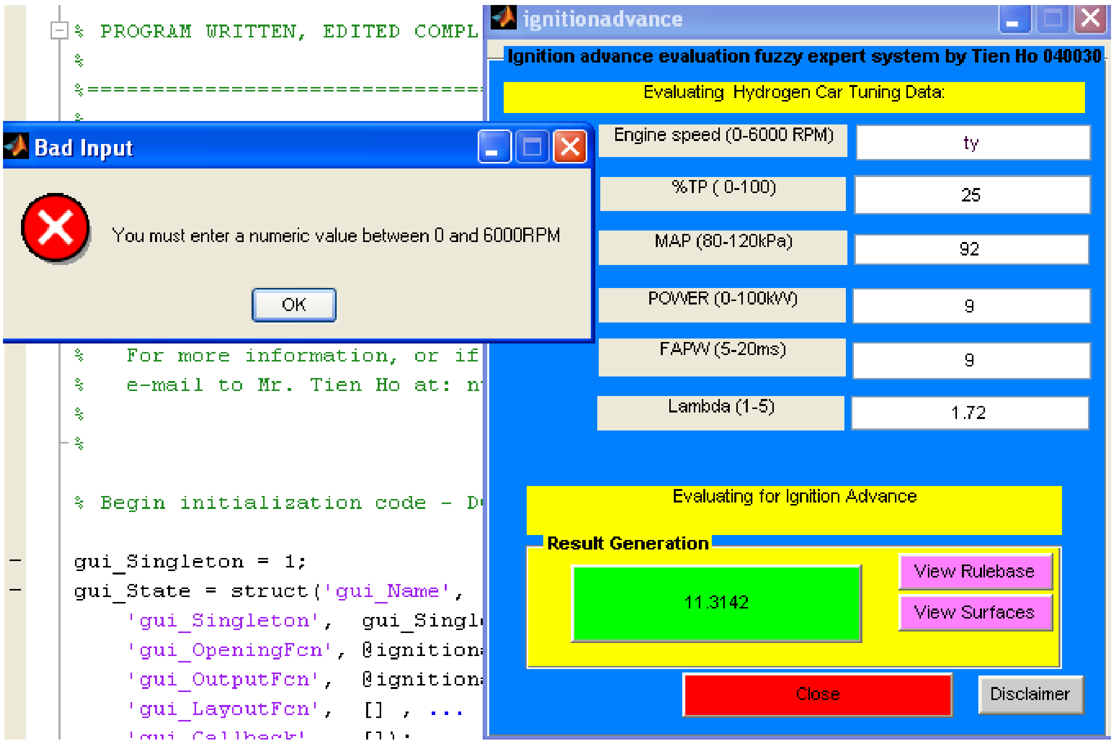


Figure 7 Dedicated error of character entered into the engine speed field

If the correct data is entered, the value will be stored and displayed in the command window so that double check can be done before entering the ignition angle value into the hydrogen engine's ECU.

It is important to note that the following buttons are included in the evaluating for ignition advance section:

Ignition advance button: press this button will display the estimation results for ignition advance at the desired engine operating condition.
View Rule base: This button allows the user to view the basic 136 rules that the expert system was based on.
View surfaces: This button enables the user to view the three dimensional surface for rule base.
Close: to close the program. Note that a dialog will appear to confirm whether the user want to close the program. If "yes" is chosen, the program will be closed.
Disclaimer: This button will show the disclaimer information.

Note that, there is no 'reset' function to reset all the values. It is simply a matter of re-entering the values and hitting the "calculate" button again.

Once the data has been entered for each of hydrogen engine operating parameters, it is necessary to press the "ignition advance" button to estimate ignition advance angle.

5. Conclusions

The intelligent fuzzy expert system has been successfully developed as a tool for the basic tuning of ignition advance of a converted hydrogen car. The program can be found in appendix 4.4 of the attached CD.

2.7 Start shaped boundary formulation of hydrogen car two-stage modelling system

The `Star Shaped` constraint is a more complex constraint with various settings that determine how your boundary model is calculated. This happens in three stages: determining the center of the data; deciding which points are on the boundary, and interpolating between those points. The star-shaped constraint is the only constraint type that can fit non-convex regions.

Star Shaped Constraint Settings

The `Star Shaped` constraint is a more complex constraint with various settings that determine how your boundary model is calculated. This is done in three stages: determining the center of the data; deciding which points are on the boundary, and interpolating between those points. These settings are detailed below.

- **Special Points > Center** — This is not the same as the Center Selection settings for RBFs, this is the method for determining the center of the boundary model sphere. The boundary model can be thought of as a deformed sphere. You can choose `Mean`, `Median`, `Mid Range`, `MinEllipse` or `User Defined`. If you select `User Defined` you can enter a value for each input.

Note You can also reach the **Special Points** settings by selecting **Constraint > Find Special Points** or the equivalent toolbar button.

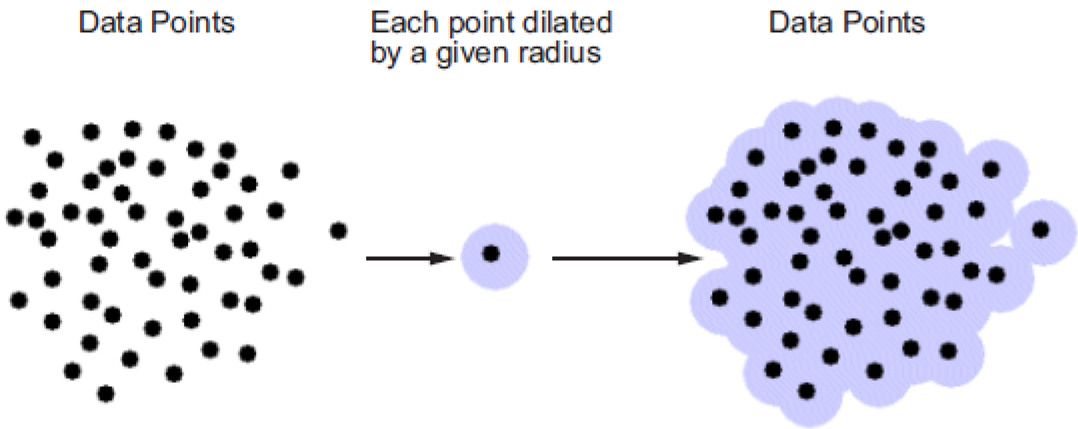
- **Boundary Points** These settings determine how to decide which points are on the boundary.

Note You can also reach the **Boundary Points** settings by selecting **Constraint > Find Boundary Points** or the equivalent toolbar button.

`Interior` — choose this if you don't want all your points to be on the boundary.

`Boundary Only` — places all points on the boundary. If this is suitable for your data then this saves time on this stage.

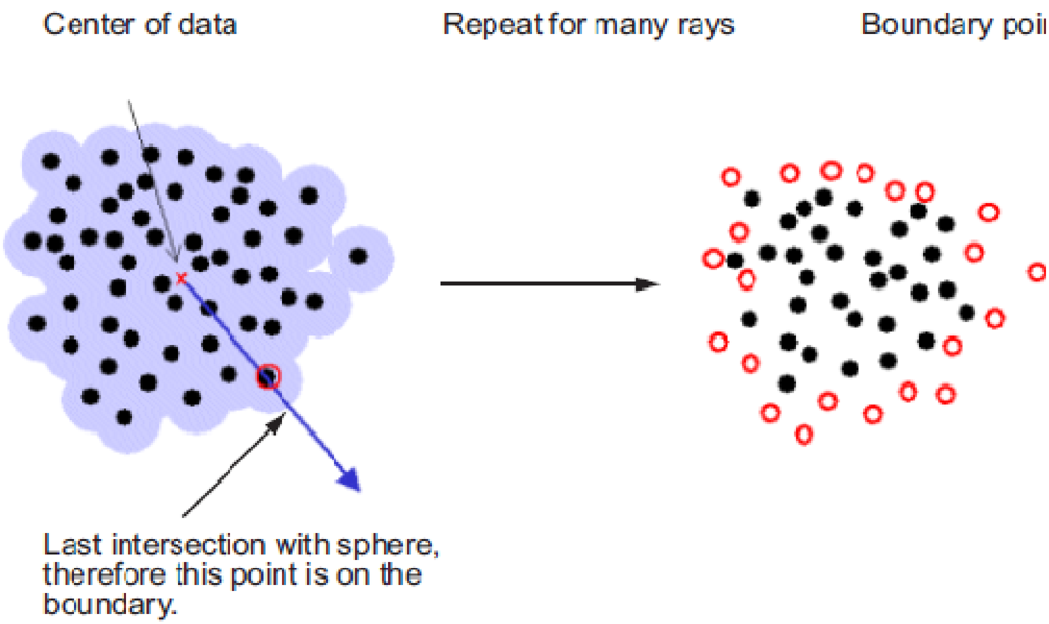
- **Dilation Radius** — If you choose `Interior` points, then **Dilation Radius** is used to determine which points are on the boundary. Each point is expanded to a sphere until a boundary shape is formed by the intersection of all those spheres. See the illustration below.



Dilation Radius settings:

- `Auto` — This setting selects the dilation radius (how much to expand each point) by checking all the minimum distances between points, then choosing the largest of those.
- `Manual` — You can manually set the dilation radius in the edit box. The default is 1. This may seem large as model range is between -1 and 1, but all points are expanded equally so you will still detect the points on the edge. However, very large spheres will intersect and obscure points that should be detected as boundary points.

- **Ray Casting** — Rays are drawn from the centre of the boundary model to determine which points are on the edge. The last point intersected on each ray is a boundary point (remember that the ray actually intersects a sphere, given that each point has been expanded by the dilation radius). See the following illustration.



Ray casting settings:

- `From Data` — This uses the same number of rays as there are data points and sends one ray in the direction of each point. If you have very dense data or a very large number of points it might be better to use the Manual setting to choose a smaller number of rays.
- `Manual` — You can set a value in the **Number of Rays** edit box. This number of rays will then be used in random directions. A good guide is about twice the number of data points, though if you have a large number (many hundreds) it will become very slow and you may run out of memory. In most situations more than 1000 is too many.

- **Constraint Fit Options.**

Note You can also reach the **Constraint Fit Options** settings by selecting **Constraint > Fit Constraint** or the equivalent toolbar button.

- **Transform** — `None`, `Log`, or `McCallum`. The default is `None`. Depending on the shape of your boundary, you might need to use a transform to prevent self intersections near the center of the model.

- **Radial Basis Function** (RBF) settings — you can choose RBF kernels, width and continuity as when setting up models. See "Global Model Class: Radial Basis Function" on page 5-75 for more information. Once the boundary points have been determined, each of those points is used as an RBF center and the boundary surface is obtained by interpolating radial basis functions between all those centers. The width and continuity settings depend on which kernel you choose.
- **RBF Algorithm**

  These options control the interpolating RBF model settings. You can leave the defaults unless you have a very large data set (several thousand points). With very large data sets it can help speed and robustness of fitting to try a different Algorithm setting here (e.g. try GMRES first) and vary the tolerance and number of iterations.

2.8 Different radial basic function kernels and structures

A radial basis function has the form

$$z(x) = \phi(\|x - \mu\|)$$

where x is a n-dimensional vector, μ is an n-dimensional vector called the center of the radial basis function, $\|.\|$ denotes Euclidean distance, and is a univariate function, defined for positive input values, that we shall refer to as the profile function.

The model is built up as a linear combination of N radial basis functions with N distinct centers. Given an input vector x, the output of the RBF network is the activity vector $\hat{y}$ given by

$$\hat{y}(x) = z\sum_{j=1}^{N} \beta_j z_j(x)$$

where β_j is the weight associated with the jth radial basis function, centered at μ_j, and $z_j = \Phi(\|x - \mu_j\|)$. The output $\hat{y}$ approximates a target set of values denoted by y.

A variety of radial basis functions are available in MBC, each characterized by the form of Φ. All of the radial basis functions also have an associated width parameter σ, which is related to the spread of the function around its center. Selecting the box in the model setup provides a default setting for the width. The default width is the average over the centers of the distance of each center to its nearest neighbor. This is a heuristic given in Hassoun (see "References" on page 7-34) for Gaussians, but it is only a rough guide that provides a starting point for the width selection algorithm.

Another parameter associated with the radial basis functions is the regularization parameter λ. This (usually small) positive parameter is used in most of the fitting algorithms. The parameter λ penalizes large weights, which tends to produce smoother approximations of y and to reduce the tendency of the network to overfit (that is, to fit the target values y well, but to have poor predictive capability).

The following sections explain the different parameters for the radial basis functions available in the Model-Based Calibration Toolbox™ product, and how to use them for modeling.

How to Choose a Kernel

Within the Model Setup dialog box, you can choose which RBF kernel to use. Kernels are the types of RBF (multiquadric, gaussian, thinplate, and so on). These types are described in the following sections.

Gaussian

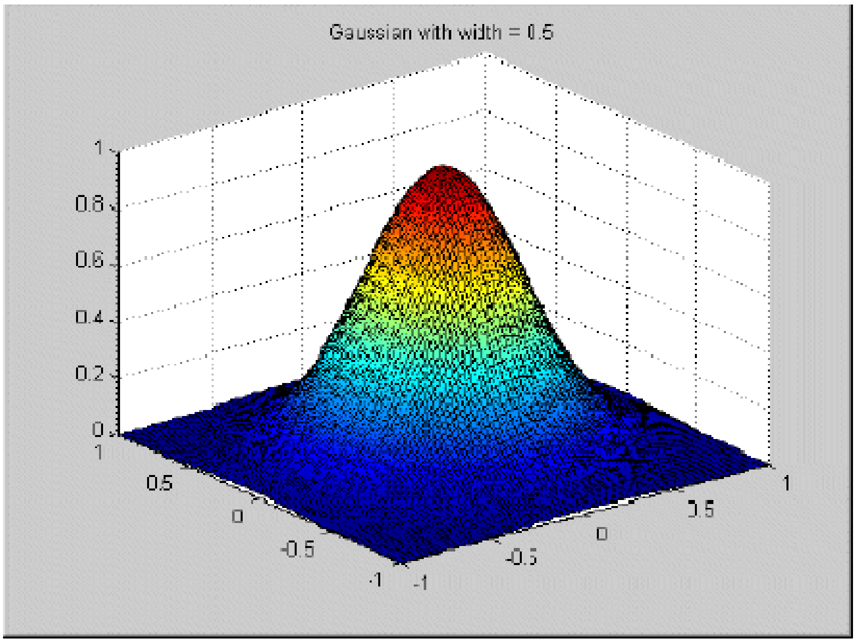
This is the radial basis function most commonly used in the neural network community. Its profile function is

$$\Phi(r) = e^{(-r^2/\sigma^2)}$$

This leads to the radial basis function

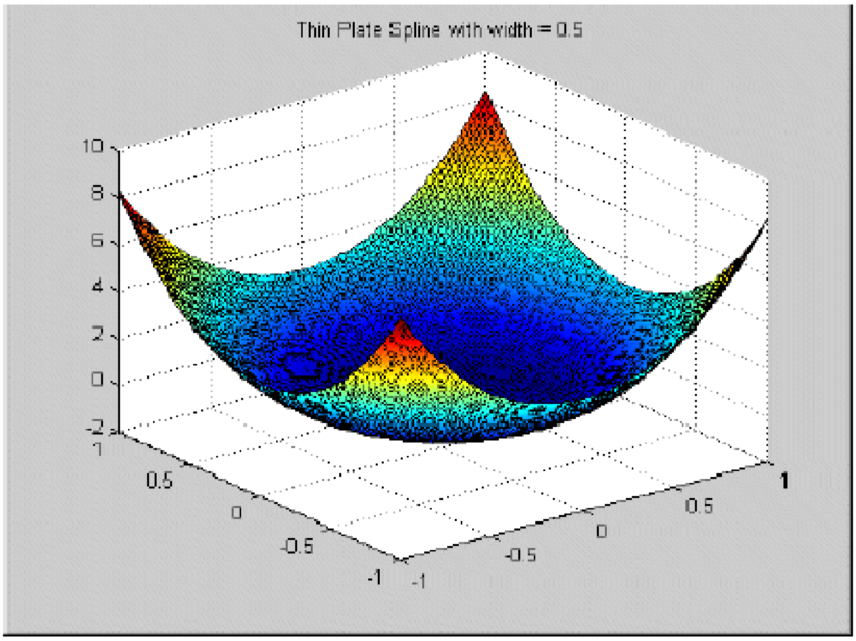
$$z(x) = \exp\left(\frac{\|x-\mu\|^2}{\sigma^2}\right)$$

In this case, the width parameter is the same as the standard deviation of the gaussian function.



Thin-Plate Spline

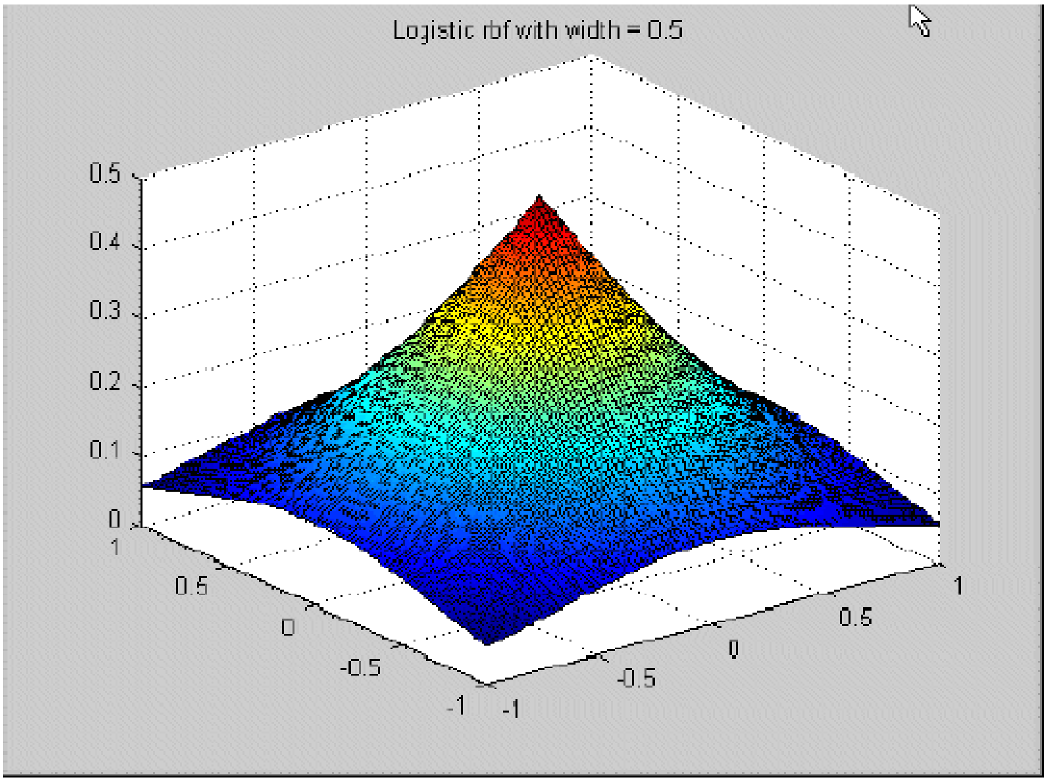
This radial basis function is an example of a smoothing spline, as popularized by Grace Wahba (`http://www.stat.wisc.edu/~wahba/`). They are usually supplemented by low-order polynomial terms. Its profile function is


Thin Plate Spline with width = 0.5
10
8
6
4
2
0
-2
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1

Logistic Basis Function

These radial basis functions are mentioned in Hassoun (see "References" on page 7-34). They have the profile function

$$\Phi(r) = \frac{1}{1 + \exp(\frac{r}{\sigma})}$$



Wendland's Compactly Supported Function

These form a family of radial basis functions that have a piecewise polynomial profile function and compact support [Wendland, see "References" on page 7-34]. The member of the family to choose depends on the dimension of the space (n) from which the data is drawn and the desired amount of continuity of the polynomials.

Dimension	Continuity	Profile
n=1	0	$\Phi(r)=(1-r)_+$
	2	$\Phi(r)=(1-r)_+^3(3r+1)$
	4	$\Phi(r)=(1-r)_+^5(8r^2+5r+1)$
n=3	0	$\Phi(r)=(1-r)_+^2$
	2	$\Phi(r)=(1-r)^4+(4r+1)$
	4	$\Phi(r)=(1-r)_+^6(35r^2+18r+3)$
n=5	0	$\Phi(r)=(1-r)_+^3$
	2	$\Phi(r)=(1-r)_+^5(5r+1)$
	4	$\Phi(r)=(1-r)_+^7(16r^2+7r+1)$

We have used the notation $a_+ := \begin{cases} a, a>0 \\ 0, a\le 0 \end{cases}$ for the positive part of a.

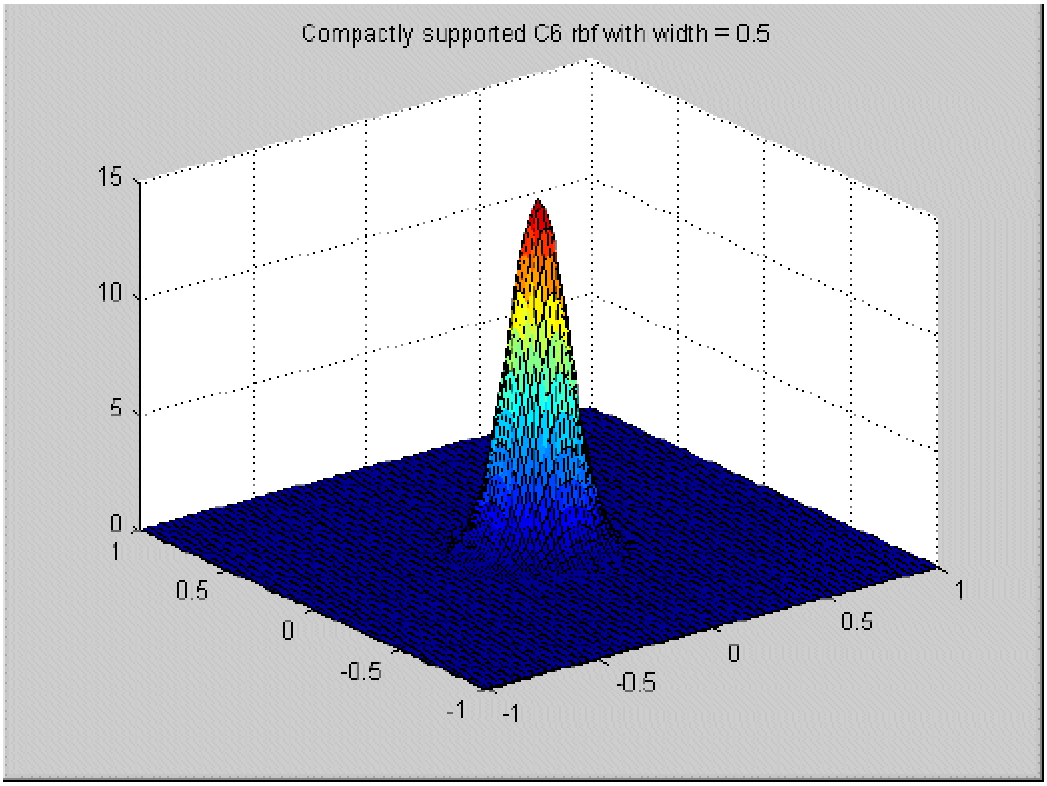
When n is even, the radial basis function corresponding to dimension n+1 is used.

Note that each of the radial basis functions is nonzero when r is in [0,1]. It is possible to change the support to be $[0,\sigma]$ by replacing r by r/σ in the preceding formula. The parameter σ is still referred to as the width of the radial basis function.

Similar formulas for the profile functions exist for n>5, and for even continuity > 4. Wendland's functions are available up to an even continuity of 6, and in any space dimension n.

Notes on Use

- Better approximation properties are usually associated with higher continuity.
- For a given data set the width parameter for Wendland's functions should be larger than the width chosen for the Gaussian.



Multiquadrics

These are a popular tool for scattered data fitting. They have the profile function

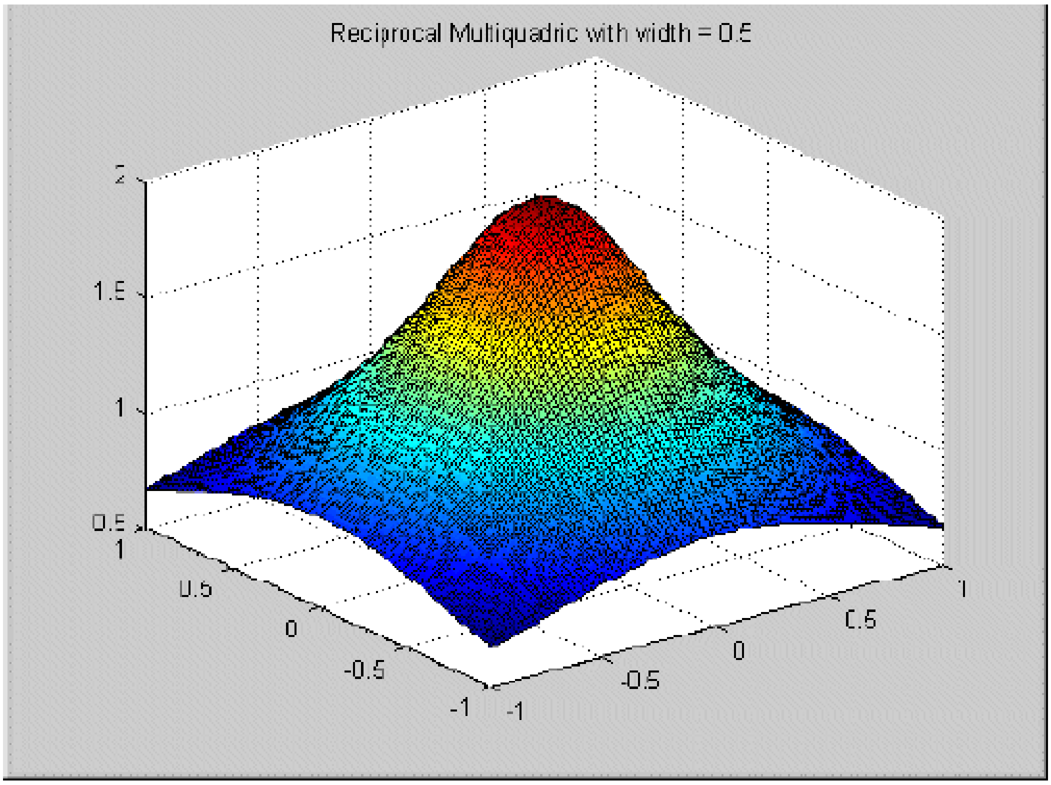
$$\Phi(r) = \sqrt{r^2 + \sigma^2_\lambda}$$

Reciprocal Multiquadrics

These have the profile function

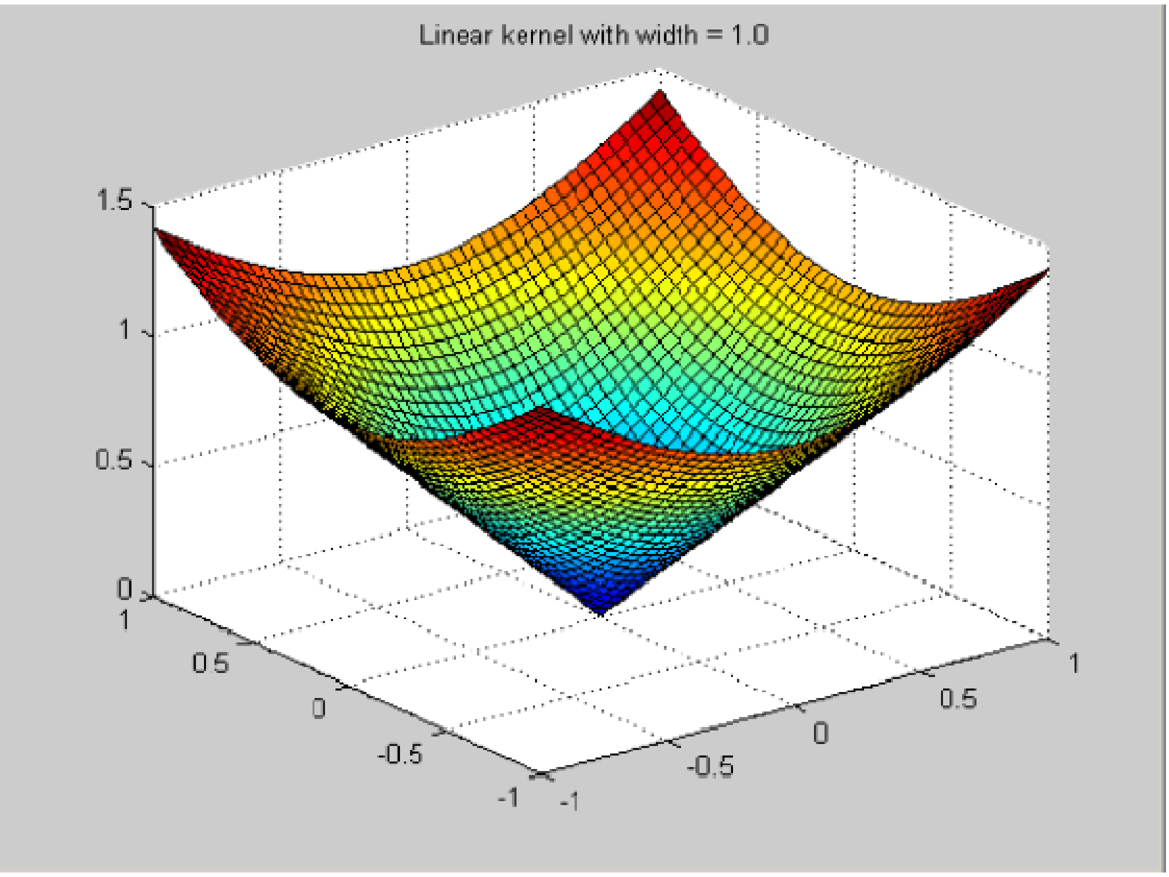
$$\Phi(r) = 1/\sqrt{r^2 + \sigma^2}$$

Note that a width σ of zero is invalid.



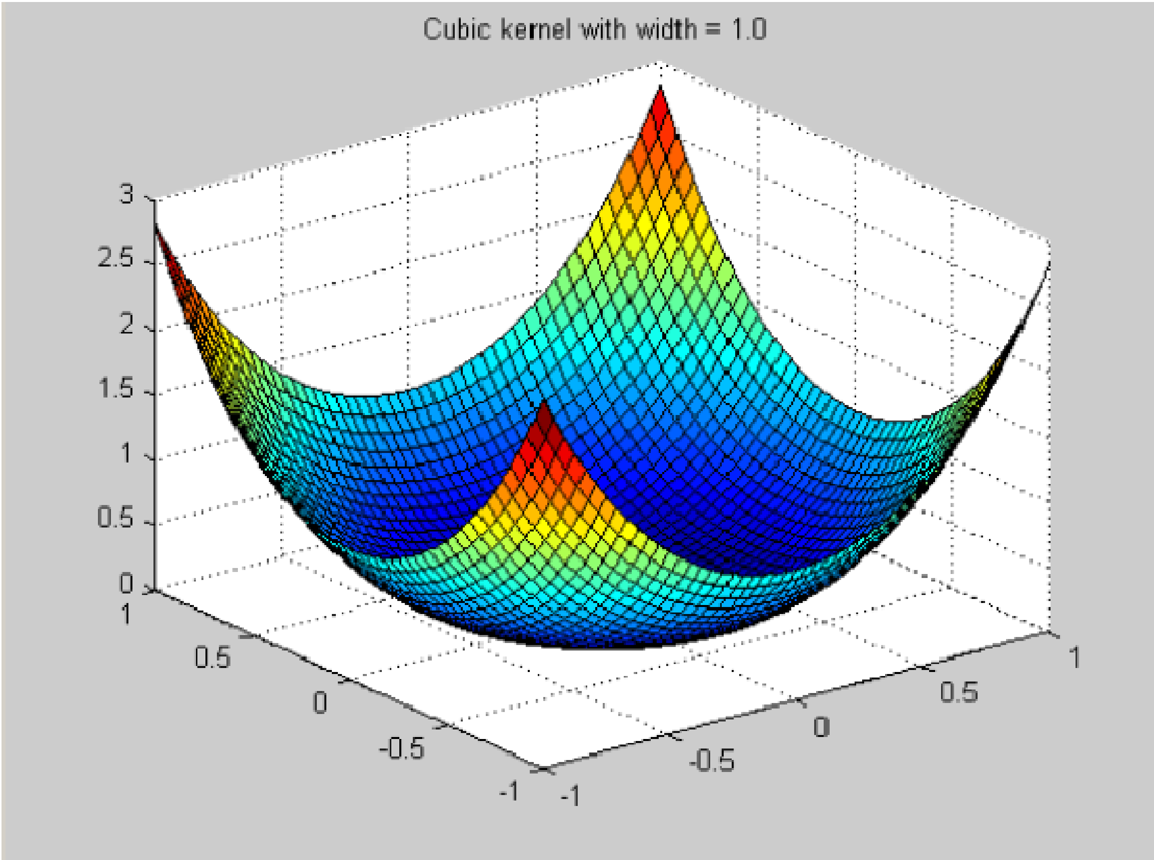
Linear

These have the profile function $\phi = -r$.



Cubic

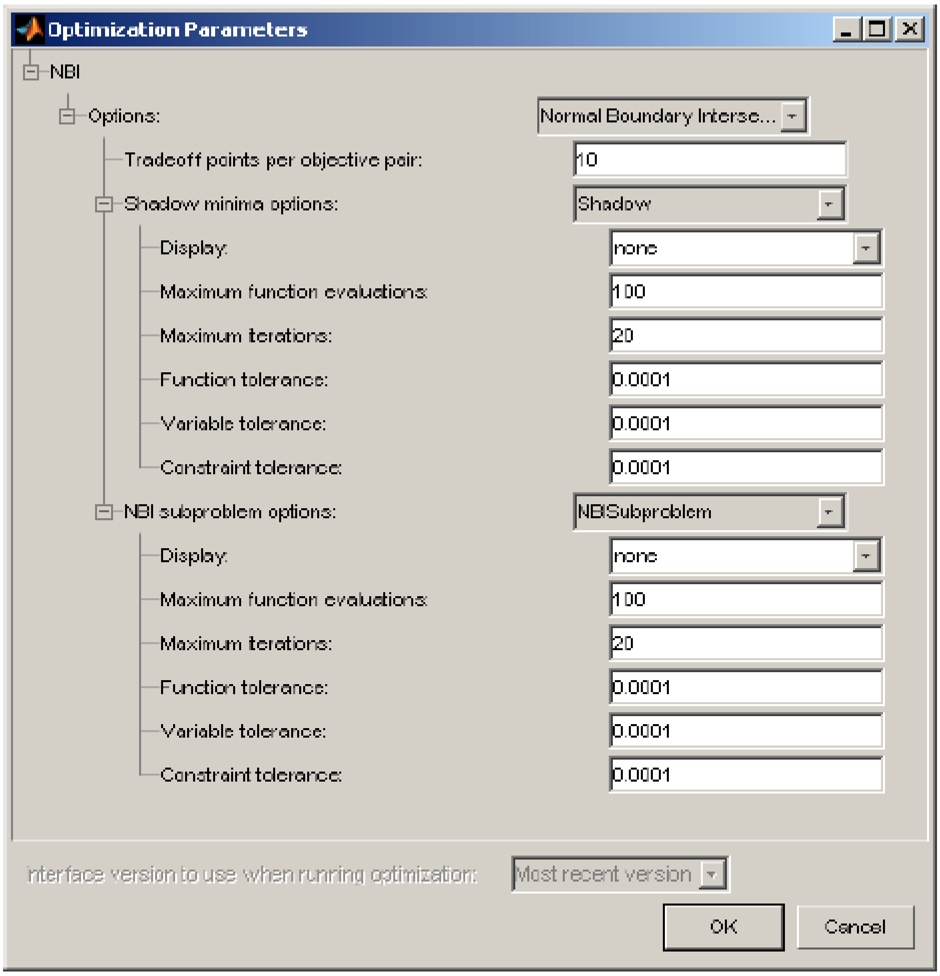
These have the profile function $\phi = r^3$.



2.9 The "NBI" multi-objective optimisation algorithm

NBI stands for Normal Boundary Intersection algorithm, which is multiobjective and can also be subject to constraints.

The example following shows the NBI options in the Optimization Parameters dialog box.



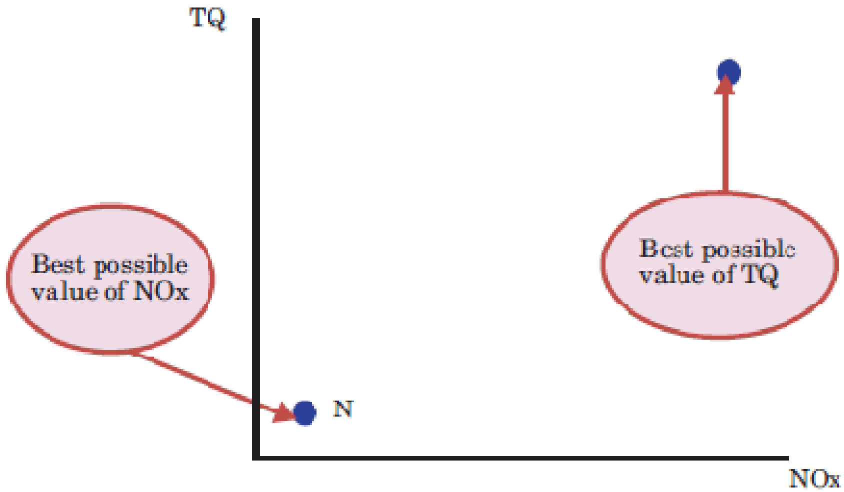
Background on the NBI (Normal Boundary Intersection Algorithm)

To understand the options for the NBI algorithm, some limited understanding of the algorithm is required. For more information on the NBI algorithm, see the NBI home page at the following URL:

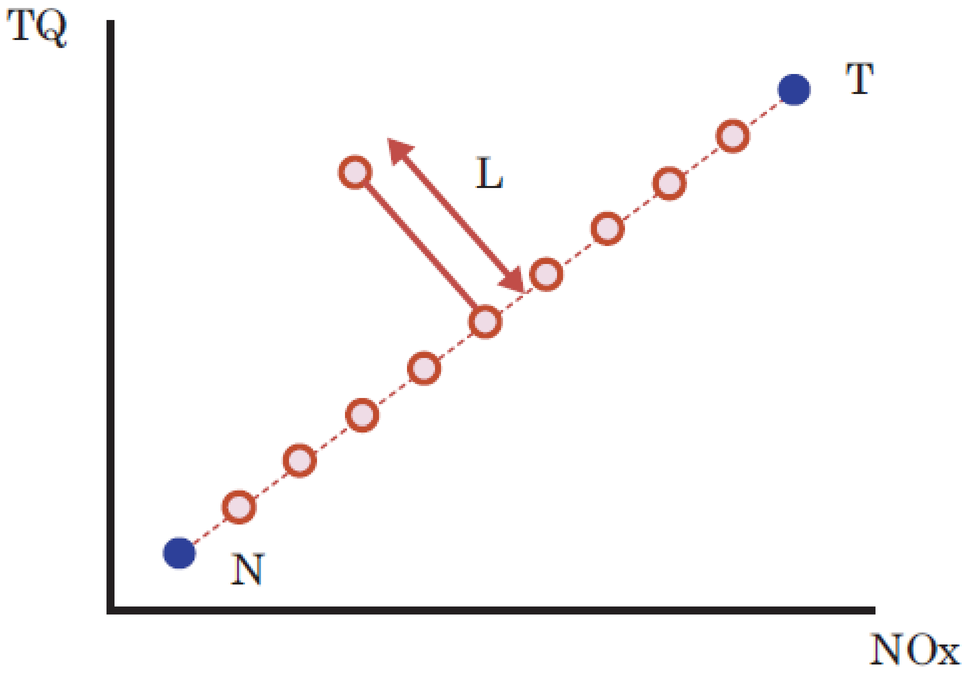
http://www.caam.rice.edu/~indra/NBIhomepage.html

The NBI algorithm is performed in two steps. The first step is to find the global of each objective individually. This is called the shadow minima problem, and is a single-objective problem for each objective function. The

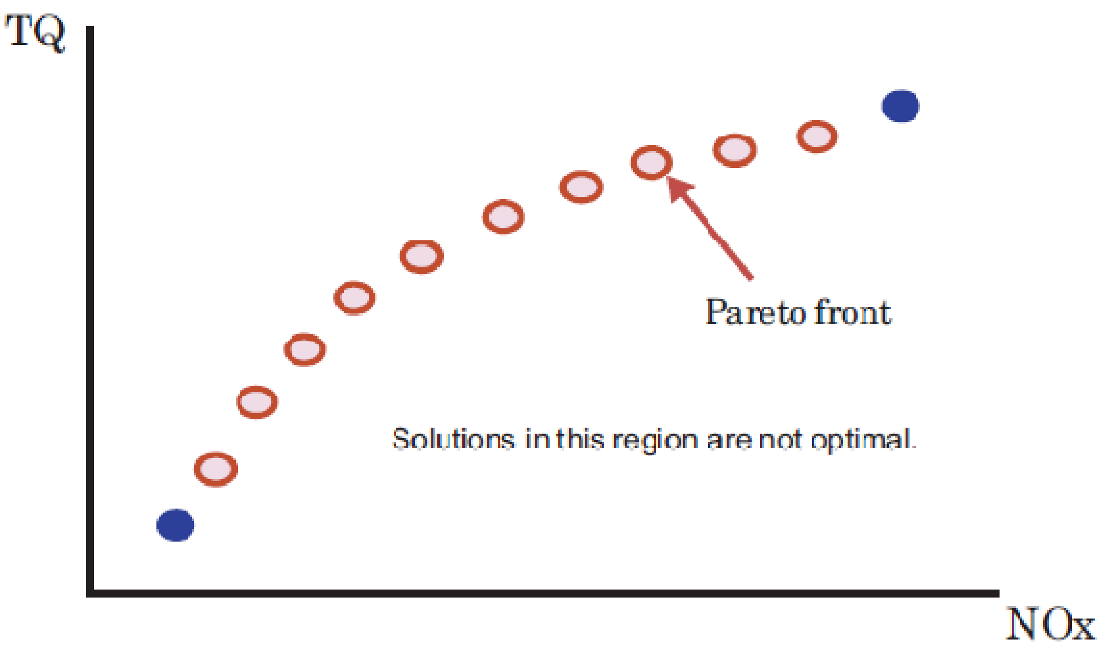
MATLAB routine `fmincon` is used to find these . Once these are found, they can be plotted against each other. For example, consider an `NBI` optimization that simultaneously maximizes TQ and minimizes NOX emissions. A plot of the against each other might resemble the following.



The second step is to find the "best" set of tradeoff solutions between your objectives. To do this, the `NBI` algorithm spaces `Npts` start points in the (n-1) hypersurface, `S`, that connects the shadow . In the above example, `S` is the straight line that connects the points `N` and `T`. For each of the `Npts` points on `S`, the algorithm tries to maximize the distance along the normal away from this surface (this distance is labeled `L` in the following figure). This is called the `NBI` subproblem. For each of the points, the `NBI` subproblem is a single-objective problem and the algorithm uses the MATLAB `fmincon` routine to solve it. This is illustrated below for the TQ-NOX example.



The figure above shows spacing of the points between the along the (n-1) surface. The algorithm tries to maximize the distance L along the normal away from the surface. The following figure shows the final solution found by the NBI algorithm.



NBI Options

- **Tradeoff points per objective pair** (`Np`)

  The number of tradeoff solutions between your objectives that you want to find, `Npts`, is determined by the following formula:

$$Npts = \binom{n + Np - 2}{Np - 1}$$

  where

  - `Np` is the number of points per objective pair.
  - `n` is the number of objective functions.

Note the following:

- For problems with two objectives (n = 2),

$$Npts = Np$$

- For problems with three objectives (n = 3),

$$Npts = \frac{Np(Np+1)}{2}$$

- **Shadow minima options and NBI subproblem options**

  The NBI algorithm uses the MATLAB `fmincon` algorithm to solve the shadow minima problem and the NBI subproblems, the options available are similar to those for the `foptcon` library function. For more information on these options, see the previous section, "foptcon Optimization Parameters" on page 6-48.

NBI Output Messages

The NBI algorithm provides exit messages that can be seen in the Optimization output view, in the **Solution Information** pane, for the currently selected run. Check these messages to check for problems with your optimization.

All possible exit flags and messages are shown in the following table.

Exit flag	Message
6	The shadow minima do not differ from one another. This suggests that all objectives can be minimized simultaneously. Check that the objectives are competing or alter tolerances.
1	All shadow and NBI subproblems converged to a solution.
0	At least one of the NBI subproblems is infeasible.
0	The maximum number of function evaluations was reached in at least one of the shadow or NBI subproblems.
-1	Optimization terminated prematurely by the user.
-2	At least one of the shadow problems is infeasible.
-7	At least one of the Pareto solutions is dominated.

2.10 Statistical evaluation criteria and definitions

Term	Definition
Measured Value	Actual measured value that was recorded in database during experimental testing.
Predicted Value	The predicted value is the value that was calculated/ predicted

	by using different intelligent tool in the project. The predicted value is compared against measured value to demonstrate the accuracy.
Deviation	Deviation is the difference between the predicted and measured values. It is also called as error (value).
Statistical Terms	
Average Error (value)	Average deviation between measured and predicted values. Average error is calculated as below: $$\frac{1}{N}\sum_{i=1}^{N}[(actual\ value)_i - (predicted\ value)_i]$$
Mean Error (value)	The value of mean error will indicate the average deviation of predicted values comparing with actual measured values.
Standard Deviation (value)	Standard deviation indicates variability of error. It is calculated as below: $$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$
Percentage of Average Error (%)	Percentage of Average error is calculated as below $$\frac{1}{N}\sum_{i=1}^{N}\left[\frac{(actual\ value)_i - (predicted\ value)_i}{(actual\ value)_i} \times 100\right]$$
RMS Error (value)	The RMS error is calculated as below $$\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[(actual\ value)_i - (predicted\ value)_i\right]^2}$$
Average Measured (value)	Average measured value is calculated as below $$\frac{1}{N}\sum_{i=1}^{N}[(actual\ value)_i]$$

Percentage of RMS Error (%)	The % RMSE is calculated as below $$\frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[(actual\ value)_i - (predicted\ value)_i\right]^2}}{average\ actual\ value}\times 100$$

2.11 Hydrogen Conversion Equipment

2.11.1 Quantum injectors

GASEOUS FUEL INJECTOR

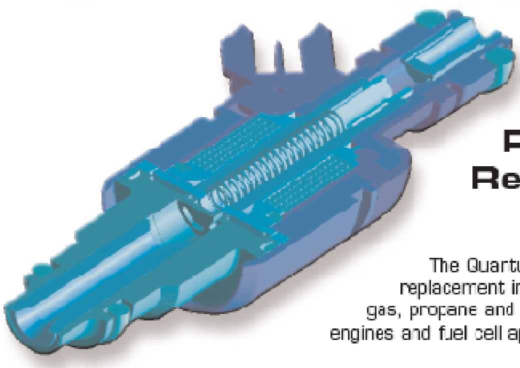
QUANTUM TECHNOLOGIES

Fuel Storage | Fuel Metering | Electronic Controls | Systems Integration | Contract Services | Engineered Products | H_2 Refueling

At Quantum, we design and manufacture state-of-the-art fuel storage, fuel metering and electronic controls, and provide advanced systems integration services that bring concept to reality for the world's largest automotive and non-automotive original equipment manufacturers of fuel cell products and alternative fueled motor vehicles.

Specializing in internal combustion engine and fuel cell applications including:

- Automotive
- Truck
- Bus
- Industrial
- Marine
- Aerospace
- Defense
- Power Generation
- Hydrogen Refueling



The First Injector to Handle Your Power & Flow Requirements.

The Quantum gaseous fuel injector is a direct replacement injector designed to work with natural gas, propane and hydrogen in internal combustion engines and fuel cell applications.

Existing injector designs suffer from premature failure in dry gas applications, orifice contamination and insufficient flow capacity for today's applications. Quantum's multi-port gaseous fuel injector addresses these shortcomings. Furthermore, the Quantum gaseous fuel injector is the first automotive-type fuel injector capable of handling the high flow rate fuel delivery requirements of 300+ horsepower V8 engines.

A simple design to provide freedom from frictional wear and sticking allows for enhanced durability. Quantum's gaseous fuel injector is designed to achieve over 500 million cycles.

FEATURES

- Suitable for all port injection internal combustion engines and fuel cell applications.
- Unique disc valve design permits high gas flow and sustained durability.
- Fits typical port and fuel rail applications
- Design is proven for high-volume manufacturing.
- Flexible design allows for low and high flow rates with minimal cost impact.
- Validated for use in typical automotive applications.
- Utilizes a standard electrical connector.
- Submitted for ECE-R110 approval for European applications.

DURABILITY RELIABILITY

QUANTUM TECHNOLOGIES

PRODUCT VALIDATION

- Temperature
- Vibration
- Thermal shock
- Water intrusion
- External corrosion
- Internal corrosion
- Immunity to conducted transients
- Immunity to jumpstart voltages

GASEOUS FUEL INJECTOR

ELECTRICAL INTERFACE

Connector:
Injector mates with AMP™ connector
Supply Voltage:
8-16 Volts typical
Injector Coil Characteristics:
Resistance:
2.05 +/- 0.25 Ω at 20°C
Inductance:
3.98 +/- 0.3 mH at 1000 Hz typical
Drive Circuit: Peak and Hold

The Quantum injector is a low impedance device requiring a peak and hold drive circuit. The characteristics are shown in Figure 1, where system voltage is supplied during the peak current time followed by a hold current for the remaining of the pulse.

Applying direct battery voltage to the injector during crank and the first ten seconds of run time helps make the injector performance less sensitive to fuel-born contaminants in gaseous fuel applications.

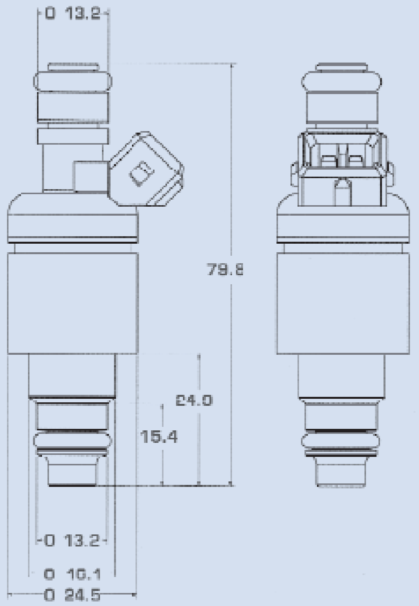
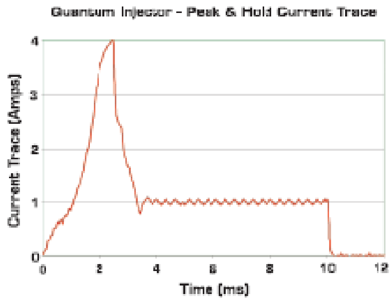


Figure 1



- **Length:** 79.8 mm
- **Diameter (Max):** 24.5 mm (excl. connector)
- **Flow Capacity (Static):**
  CNG: 2.0 g/s @ 276-310 kPa / 40-45-psi
  LPG: 2.0 g/s @ 117-138 kPa / 17-20-psi
  Hydrogen: 0.8 g/s @ 483-552 kPa / 70-80-psi
- **Working Pressure:** 103-552 kPa / 15-80-psi
- **Durability:** >500 million cycles (tested on CNG)
- **Dynamic Range:** 12:1 typical

World Headquarters
17872 Cartwright Road
Irvine, CA 92614
Voice. (949) 399-4500
Facsimile. (949) 399-4600
Web. www.qtww.com
Email. info@qtww.com

2.11.2 BOC Steel Cylinders

Steel P & L Cylinders

Size Code	Nominal Tare Weight (kg)	Nominal Height (mm)	Nominal Outside Diameter (mm)	Nominal Water Capacity (kg or litres)
K	67.0	1503	230	50.0
J	67.0	1295*	236	45.6
G	50.0	1400	232	48.0
GM	59.0	1295	232	43.3
E	28.0	910	200	23.0
D	11.0	760	150	9.41
C	3.3	460	100	2.75
B	3.5	305	85	1.42
A	1.5	180	85	0.71

*Add approx.. 260mm to height of J cylinder to allow for valve guard.

2.11.3 Swagelok Stainless Steel Tubing

Stainless Steel Tubing
Metric Sizes

Seamless Tubing

- 3 to 25 mm outside diameter
- 316/316L stainless steel
- ASTM A213①/A269

① Nominal wall thickness, not minimum wall thickness.

Steel Grades

AISI	UNS	SS	AFNOR	W.-NR.
316 / 316L	S31603	2353	Z2CND17-13	1.4435

Typical Chemical Composition

Element	Composition wt. %
Carbon	≤ 0.03
Chromium	17
Nickel	13
Molybdenum	2.6

Ordering Information

Nominal OD mm	Nominal Wall Thickness mm	Ordering Number	Nominal Length m	Weight kg/m	Allowable Working Pressure bar
3	0.5[1]	SS-T3M-S-0,5M-6ME		0.021	340
	0.7	SS-T3M-S-0,7M-6ME		0.027	500
6	1.0	SS-T6M-S-1,0M-6ME		0.125	420
	1.5	SS-T6M-S-1,5M-6ME		0.169	710
8	1.0	SS-T8M-S-1,0M-6ME		0.175	310
	1.5	SS-T8M-S-1,5M-6ME		0.244	520
10	1.0	SS-T10M-S-1,0M-6ME		0.225	240
	1.5	SS-T10M-S-1,5M-6ME		0.319	400
12	1.0	SS-T12M-S-1,0M-6ME		0.275	200
	1.5	SS-T12M-S-1,5M-6ME		0.394	330
	2.0	SS-T12M-S-2,0M-6ME	6	0.500	470
16	1.0[1]	SS-T16M-S-1,0M-6ME		0.375	140
	1.5	SS-T16M-S-1,5M-6ME		0.507	230
	2.0	SS-T16M-S-2,0M-6ME		0.651	330
18	1.0[1]	SS-T18M-S-1,0M-6ME		0.425	120
	1.5	SS-T18M-S-1,5M-6ME		0.619	200
	2.0	SS-T18M-S-2,0M-6ME		0.801	290
20	2.0	SS-T20M-S-2,0M-6ME		0.901	260
22	2.0	SS-T22M-S-2,0M-6ME		1.00	230
25	2.0[2]	SS-T25M-S-2,0M-6ME		1.15	200
	2.5	SS-T25M-S-2,5M-6ME		1.41	260

[1] Not recommended for use with Swagelok tube fittings.
[2] Not recommended for use with Swagelok tube fittings in gas service.

Tools and Accessories

See the Swagelok *Tools and Accessories* catalog, MS-01-169, for more information.

Tube Supports

See the Swagelok *Tube Supports* catalog, MS-01-109, for more information.

Tube Fittings

See the Swagelok *Gaugeable Tube Fittings and Adapter Fittings* catalog, MS-01-140, for more information.

Swagelok Orbital Welding System

See the Swagelok *Orbital Welding System Quick Reference Guide*, MS-02-143, for more information.

2.11.4 CIGWeld Comet Regulator

SECTION TWO

GAS EQUIPMENT
REGULATORS – WELDING, CUTTING, HEATING

GAS EQUIPMENT

Genuine COMET™ 700 OXYGEN & ACETYLENE REGULATORS WITH GASGUARD™

Part No.	Gas	Max. Outlet Pressure (kPa)	Rated Air Flow' (l/min)	Gauge Range (kPa) Inlet	Gauge Range (kPa) Outlet	Connections Inlet	Connections Outlet
301637	Oxygen	1000	1,200	30,000	1,600	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'VP'	5/8"-18 UNF RH Ext
301657	Oxygen	1000	1,200	30,000	1,600	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'SI'	5/8"-18 UNF RH Ext
301531	Oxygen	400	500	30,000	1,000	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'VP'	5/8"-18 UNF RH Ext
301595	Oxygen	400	500	30,000	1,000	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'SI'	5/8"-18 UNF RH Ext
301532	Acetylene	150	200	4,000	300	AS 2473 Type 20 (5/8" BSP LH Ext)	5/8"-18 UNF LH Ext

- These revolutionary single-stage regulators incorporating our Encapsulated Seat Technology, offer steady, precise pressure and flow control of Oxygen and Acetylene under all conditions.
- The large, clear, colour-coded gauges enable both inlet and delivery to be read on site at a glance.
- In the unlikely event of the regulator failing, the pressure gauges will be fail safe, being designed to ensure that no parts are thrown.
- Oxygen max. rated flow – 1200 l/min. Acetylene max. rated flow – 285 l/min.
- Each regulator is clearly colour coded, so that the units are used with the gases for which they were designed. Further to this, left and right-hand threads on the inlet and outlet connections prevent the use of the regulators with the wrong gases.
- Independently tested to AS 4267-1995.

Applications:

The new Genuine COMET™ 700 regulators are suitable for the majority of cutting, welding and heating applications. Ideally suited for use with 'G' and 'E' size Oxygen and Acetylene cylinders.

Important: The above regulators are to be used only with the gases for which they were designed.

Spare Parts:

Gauge – 30,000 kPa Oxy	Part No. 301626
Gauge – 1,600 kPa Oxy	Part No. 301660
Gauge – 600 kPa Oxy	Part No. 301623
Gauge – 4,000 kPa Acet	Part No. 301627
Gauge – 300 kPa Acet	Part No. 301624
Inlet nipple – type 10.5	Part No. 301917
Inlet nipple – type 20	Part No. 301790
Inlet nut – type 10.5	Part No. 315039
Inlet nut – type 20	Part No. 302625
Outlet connection – RH	Part No. 302209
Outlet connection – LH	Part No. 302210
O-Ring kit T10.5 T10/20	Part No. 301073
Service tag	Part No. 315237

NOTE: To protect your product warranty and to ensure a safe, quality repair, use a CIGWELD Accredited Service Repair Agent.

CIGWELD GAS GUARD FITTED

Genuine COMET™ 700 GAUGELESS OXYGEN & ACETYLENE REGULATORS

Part No.	Gas	Max. Outlet Pressure (kPa)	Rated Air Flow' (l/min)	Gauge Range (kPa) Inlet	Gauge Range (kPa) Outlet	Connections Inlet	Connections Outlet
301533	Oxygen	1000	1,200	-	-	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'VP'	5/8"-18 UNF RH Ext
301603	Oxygen	1000	1,200	-	-	AS 2473 Type 10.5 (5/8" BSP RH Ext) 'SI'	5/8"-18 UNF RH Ext
301534	Acetylene	150	200	-	-	AS 2473 Type 20 (5/8" BSP LH Ext)	5/8"-18 UNF LH Ext

- Based on the Genuine COMET™ 700 single stage regulator design, but without pressure gauges fitted.
- Cylinder pressure is indicated by a pin indicator on the side of the regulator.
- The required working pressure is set by aligning the edge of the pressure adjusting knob with the appropriate mark on the bonnet pressure scale.
- Oxygen max. rated flow – 1200 l/min. Acetylene max. rated flow – 285 l/min.

NOTE: To protect your product warranty and to ensure a safe, quality repair, use a CIGWELD Accredited Service Repair Agent.

Applications:

Gaugeless models indicate pressure by a strong durable brass pin indicator on the side of the regulator. The required working pressure is set by aligning the edge of the pressure adjusting knob with the appropriate mark on the bonnet pressure scale. Suitable for most medium to heavy duty applications where tough working environments mean it is subjected to abuse or rough treatment and gauges are often damaged.

Note: Gaugeless regulators are not included in AS4267-1995.

Spare Parts:

Pin indicator kit – Oxygen	Part No. 301631
Pin indicator kit – Acetylene	Part No. 301632
O-Ring kit T10.5 T10/20	Part No. 301073

2.11.5 IE5 Injector Emulator

GASTEC

INJECTOR EMULATOR – MODEL IE5

Congratulations! You have just purchased one of the most innovative Injector Emulators that is available on the world market today. Considerable testing has been performed on this product which comes with a three (3) year, unlimited km warranty.

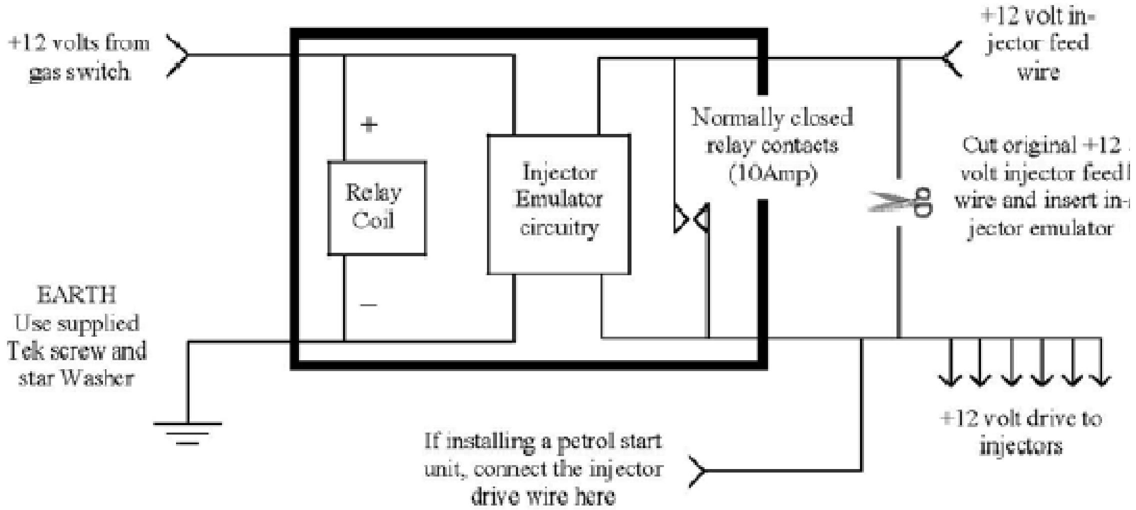
The IE5 is designed for vehicles that sense fuel injector operation by either of the following conditions :

- **Detecting current drain or**
- **Detecting voltage drop or**
- **Detecting small, back EMF (inductive) pulses from the injectors as they close.**

The IE5 has been tested on the following vehicles :

Mitsubishi Magna (most EFI models)
Mitsubishi Verada (most EFI models)
Mitsubishi Pajero (most EFI models)
Jeep (All EFI models)
Holden Jackaroo
Holden Rodeo

This Injector Emulator is designed to shut down the +12 volt feed to the injectors as shown below. The IE5 can drive 4, 6 or 8 injectors.



Quality *GASTEC* products can been found in Europe, Asia and Australia.

Other ***GASTEC*** Products include :

- **LPG and CNG Fuel Processors for EFI vehicles.**
- **Petrol start devices for EFI vehicles.**
- **20mm round, 2 and 3 position switches.**
- **20mm round, 90 ohm gauges.**
- **LPG and CNG Safety Switches.**

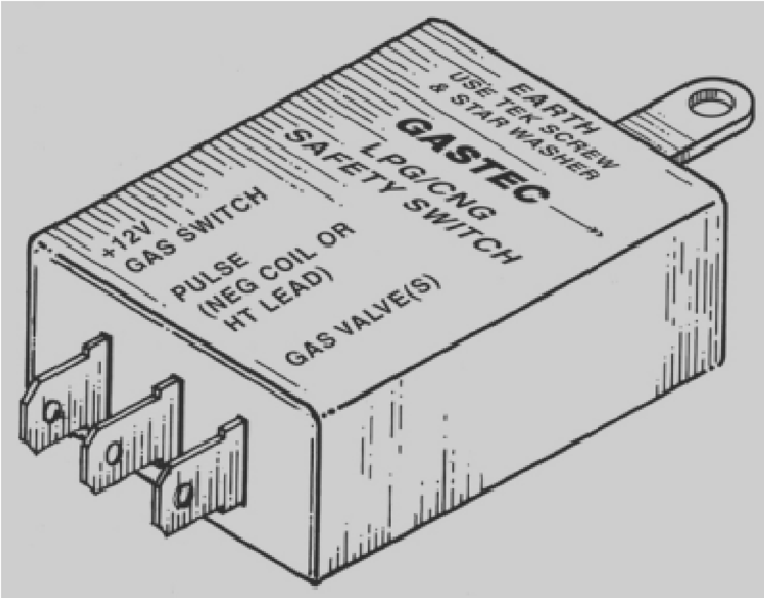
2.11.6 Safety Switch

GASTEC CORPORATION

ELECTRONIC CONTROLS TO CONVERT VEHICLES TO OPERATE ON LPG, CNG & DIESEL FUMIGATION

LPG and CNG SAFETY SWITCH

MODEL SD40



Terminals

- Earth
- +12V Ignition
- Output Terminal to Drive Gas Valves
- Input pulse wire from negative coil or 10 tight turns around HT lead – single sheathed hookup wire, taped securely in place.

Other Specifications

- 10 Amp Relay
- Expected Life = 1 million operations electrical at full load DC and 450,000 operations with three gas valves (MED type, 12 volt DC with resistant windings at 11.5 ohms cold), 5 million operations mechanical

2.11.7 Hydrogen Sensor

RKI INSTRUMENTS

STAND ALONE EXPLOSION PROOF TRANSMITTER

Gas Detection For Life — **M2 Series**

Features

- Operates independent of a controller
- Direct digital readout on backlit LCD
- Available for LEL, H_2S, CO, and O_2
- 4-20 mA & digital Modbus outputs standard
- Non-intrusive calibration via magnetic wand
- 2 fully programmable alarm relays & fail relay
- H_2 specific LEL version available
- Infrared combustible version available
- Patented water repellent sensor coating
- User friendly setup push buttons & LCD menus
- Intrinsically safe, CSA, C/US classified

Industry Applications

- Petrochemical plants
- Refineries
- Offshore drilling platforms
- Water & wastewater treatment plants
- Pulp & paper mills
- Gas, telephone, & electric utilities
- Parking garages
- Manufacturing facilities
- Steel
- Automotive

The RKI M2™ is a state-of-the-art transmitter that can operate as an independent, stand-alone system or as part of a system connected with an analog or digital signal to virtually any controller, PLC, or DCS. The M2 series detects LEL combustibles, oxygen, hydrogen sulfide, or carbon monoxide. It utilizes a magnetic wand technique for performing non-intrusive calibration. The M2 provides an automatic zero drift correction feature, which results in more stable readings and reduces the need for adjustments due to sensor aging.

The housing of the M2 does not need to be opened for zeroing or calibration, making it unnecessary to declassify the area for routine maintenance. It is designed so that a complete field calibration can be performed by one person. The stainless steel flame arrestor housing that covers the sensor (LEL, H_2S, CO, or XP Oxygen) is water repellent with a special patented water resistant coating.

The transmitter provides a 4-20 mA output in addition to a Modbus digital output. It also has two levels of alarm with relays, plus a fail alarm with a relay. A digital display of the gas concentration, as well as alarm and status lights can be viewed through the front window.

The M2 represents the latest leading edge technology in sensor / transmitters today.

RKI Instruments, Inc. • 33248 Central Ave. Union City, CA 94587 • Phone (800) 764-5165 • (510) 441-5656 • Fax (510) 441-5650

World Leader In Gas Detection & Sensor Technology
www.rkiinstruments.com

2.11.8 Solenoid Shut-Off Device

Technical Specification Sheet unavailable. The following data is provided by the supplier[1].

Maximum working pressure	20 MPa
Power Supply	12VDC
Inlet Connection	¼" NPT
Outlet Connection	¼" NPT

[1]For further information, please contact the supplier:

Apollo Gas Pty. Ltd.
Factory 1 & 2, 42 Burgess Road,
Bayswater North,
Victoria, 3153

Phone: (03) 9761 7883
Fax: (03) 9761 7884

2.11.9 Tesuco Flashback Arrestor

TESUCO TECHNICAL SUPPLIES COMPANY

GAS SAFETY ENGINEERING

IBEDA

SIMAX High Flow Manifold Flashback Arrestors

SAFETY FEATURES

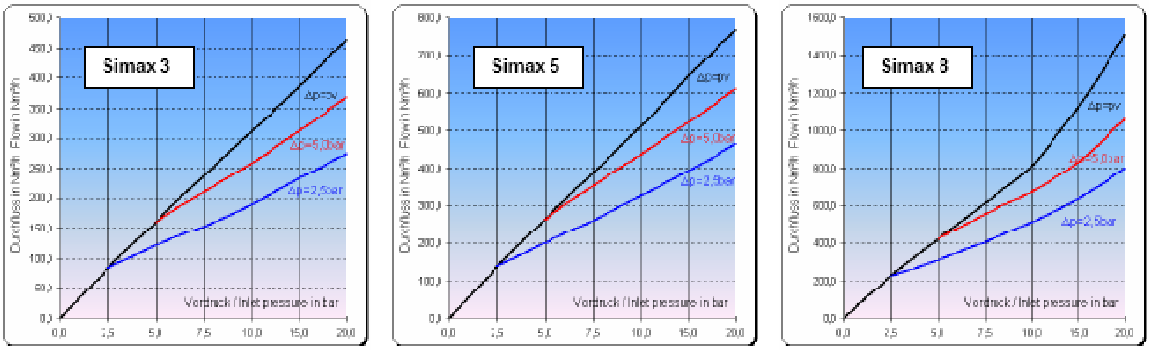
- **Inlet Filter**
- **Gas Non-Return Valve**
- **Sintered Element(s)**
- **Thermal Cut-off Valve**

Maximum Working Pressure	
Gas	kPa
Acetylene	150
Hydrogen	500
LPG	500
Oxygen	2,100

Part No	Description
0701-3173	Simax 3 - Fuel, 3 x DG91N
0701-3175	Simax 5 - Fuel, 5 x DG91N
0701-3178	Simax 8 - Fuel, 8 x DG91N
0701-3195	Simax 3 - Oxygen, 3xDG91N
0701-3196	Simax 5 - Oxygen, 5xDG91N
0701-3197	Simax 8 - Oxygen, 8xDG91N

Conversion Factors	
Acetylene	X 1.04
Hydrogen	X 3.75
LPG	X 1-0.8 *
Oxygen	X 0.95
Air	X 1.00

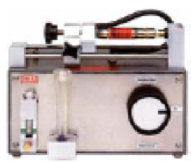
* Dependent on composition



Testing To Requirements in AS 4603-1999

"Testing on Flashback Arrestors in service shall be carried out at a minimum interval of twelve months"

It is essential that flashback arrestors continue to perform to the manufacturer's minimum specifications. Flashback arrestors performing below these specifications may, in fact, be the cause of an accident, by not supplying the required flow rate for an application or by allowing reverse flow.



Features and Benefits

All arrestors are filled with a stainless steel sintered element – which stops a flashback by quenching the heat, a non-return valve to stop the reverse flow of gas and a replaceable inlet filter that protects the arrestor from contaminants giving it a longer service life. A thermal cut-off valve is incorporated into the design of all regulator end flashback arrestor models to guard against burn backs. The arrestors are designed to operate to a maximum working pressure of 2,100 kPa meeting the requirements of AS 4289 and each arrestor is individually leak and flame tested to ensure functionality. Tesuco is responsible for the distribution of the full range of IBEDA flashback arrestors throughout Australia so you can be assured that there will be an arrestor available to suit every requirement.

For further information, please contact Tesuco Pty Ltd
Syd: (02) 9638 4433 **Mlb**: (03) 9775 6223 **Brs**: (07) 3806 4129 **Freecall**: 1800 631 511

3 APPENDIX 3: RECORDED DATA

3.1 Hogen.m data

water quality	water flow	water temp	water pressure	stack voltage	stack current	system temp	stack current PWR102	system pressure	board temp	gas detect	product pressure	hydro flow rate
14.5	0.0748	14.79	286.91	23.7	144	17	992	190	12	38	190	8.97
14.1	0.0748	14.84	287.30	23.8	144	17	992	190	12	36	190	8.97
14.1	0.0748	14.84	286.91	23.8	144	17	992	190	12	36	190	8.98
14.2	0.0748	14.84	287.50	23.9	144	17	992	189	12	32	191	8.97
14.3	0.0748	14.84	287.70	23.9	143	17	992	190	12	30	190	0.12
14.3	0.0748	14.84	286.91	23.9	143	17	992	190	12	30	190	0.13
14.3	0.0748	14.84	287.11	23.9	143	17	992	191	12	30	190	0.13
14.2	0.0748	14.84	286.91	23.8	143	17	26	190	13	30	190	0.13
14	0.0748	14.89	286.91	16.1	6	17	26	199	13	30	200	0.13
13.5	0.0748	14.84	287.11	16.2	6	15	26	201	12	31	200	0.13
13.5	0.0748	14.84	286.91	16.2	6	15	26	201	12	31	200	0.13
13.5	0.0748	14.84	287.50	16.2	6	15	26	201	12	31	200	0.13
13.6	0.0748	14.84	287.11	16.2	6	16	26	200	13	31	200	0.13
13.7	0.0748	14.89	286.72	16.2	6	16	26	200	13	30	200	0.12

13.3	0.0748	14.84	287.11	16.2	6	15	26	201	13	31	200	0.13
13.4	0.0748	14.79	286.91	16.2	6	15	26	201	13	32	200	0.12
13.5	0.0748	14.79	286.91	16.2	6	15	26	201	13	31	200	0.12
13.3	0.0748	14.84	286.72	16.2	6	15	26	199	13	32	200	0.13
13.3	0.0748	14.79	287.50	16.2	6	15	26	199	13	32	200	0.12
13.2	0.0748	14.84	286.91	16.2	6	15	26	201	13	31	200	0.12
13.3	0.0748	14.84	286.91	16.2	6	15	26	200	13	31	200	0.12
13.5	0.0748	14.79	286.52	16.1	6	15	26	200	13	31	200	0.12
13.5	0.0748	14.79	286.91	16.1	6	15	26	200	13	31	200	0.13
13.5	0.0748	14.89	286.52	16.1	6	15	26	200	13	31	200	0.13
13.5	0.0748	14.84	286.91	16.1	6	15	26	200	13	31	200	0.13
13.3	0.0748	14.84	287.11	16.2	6	15	26	201	13	31	200	0.13
13.3	0.0748	14.84	287.30	16.2	6	15	26	201	13	31	200	0.13
13.3	0.0748	14.84	286.91	16.2	6	15	26	201	12	30	201	0.13
13.3	0.0748	14.84	286.91	16.2	6	15	26	201	12	30	201	0.13
13.3	0.0748	14.84	286.72	16.2	6	15	26	201	12	30	201	0.13
13	0.0748	14.89	286.33	16.2	6	14	26	200	12	30	200	0.13
13	0.0748	14.89	286.72	16.2	6	14	26	200	12	30	200	0.13
13	0.0748	14.84	286.72	16.2	6	14	992	198	13	30	200	0.13

13.8	0.0748	14.84	287.11	24	144	17	992	189	13	32	91	8.98
14	0.0748	14.89	286.91	24	144	17	992	192	13	31	110	8.97
13.9	0.0748	14.84	286.91	24	143	17	992	192	13	30	83	0.12
13.9	0.0748	14.84	286.91	24	143	17	992	192	13	30	83	0.13
13.9	0.0748	14.84	286.72	24	143	17	992	192	13	30	83	0.13
13.9	0.0748	14.84	287.11	24	143	17	992	192	13	30	83	0.12
14	0.0748	14.84	286.13	23.9	144	18	992	195	13	28	81	8.98
13.9	0.0748	14.79	286.52	23.9	144	18	992	192	13	27	81	8.97
13.8	0.0748	14.79	286.13	23.8	144	18	992	190	13	27	79	8.97
13.9	0.0748	14.79	287.11	23.8	144	19	992	191	13	27	78	8.97
13.9	0.0748	14.84	286.33	23.8	144	19	992	191	13	27	79	8.97
14.1	0.0748	14.84	286.72	23.8	144	19	992	190	13	27	78	8.97
14.2	0.0748	14.84	286.52	23.8	144	19	992	190	13	28	78	8.97
13.9	0.0748	14.84	286.52	23.8	144	19	992	192	13	28	80	8.97
13.9	0.0748	14.79	286.72	23.8	144	19	992	192	13	28	79	8.97
14	0.0748	14.84	286.52	23.7	144	19	992	191	13	29	79	8.97
13.8	0.0484	14.79	286.72	23.7	144	19	992	192	13	29	78	8.98
13.8	0.0748	14.84	286.52	23.7	144	19	992	192	13	29	78	8.97
14.1	0.0748	14.79	286.72	23.7	144	20	992	192	13	29	79	8.97

14.4	0.0748	14.84	286.52	23.7	144	20	992	192	13	30	79	8.97
14	0.0748	14.84	286.52	23.7	144	20	992	187	13	30	63	8.98
14	0.0748	14.79	286.72	23.7	144	20	992	187	13	30	63	8.98
14	0.0748	14.79	286.33	23.7	144	20	992	187	13	30	63	8.97
14	0.0748	14.79	286.33	23.7	144	20	992	187	13	30	63	8.97
14	0.0748	14.79	286.72	23.7	144	20	992	187	13	30	63	8.97
14.4	0.0748	14.79	286.91	23.7	144	21	992	194	14	30	79	8.97
14.4	0.0748	14.79	285.74	23.7	144	21	992	194	14	30	79	8.97
14.4	0.0748	14.79	286.33	23.6	144	21	992	194	14	30	79	8.97
14.4	0.0748	14.79	286.72	23.6	144	21	992	194	14	30	79	8.97
14.4	0.0748	14.79	285.94	23.6	144	21	992	194	14	30	79	8.97
14.4	0.0748	14.79	286.13	23.6	144	21	992	194	14	30	79	8.98
14.4	0.0748	14.84	285.94	23.6	144	21	992	194	14	30	79	8.98
14.4	0.0748	14.79	286.72	23.6	144	21	992	194	14	30	79	8.97
14.3	0.0748	14.79	286.33	23.6	144	21	992	184	14	30	70	8.97
14.3	0.0748	14.84	286.33	23.6	144	21	992	194	14	30	60	8.97
14.3	0.0748	14.79	286.33	23.6	144	21	992	194	14	30	60	8.98
14.5	0.0748	14.84	285.94	23.6	144	22	992	194	14	30	77	8.97
14.4	0.0748	14.84	286.52	23.6	144	22	992	195	14	30	78	8.97

14.3	0.0748	14.79	286.33	23.6	144	22	992	194	14	30	79	8.97
14.3	0.0748	14.79	286.33	23.6	144	22	992	194	14	30	79	8.98
14.5	0.0748	14.75	286.33	23.6	144	22	992	193	14	30	80	8.97
14.4	0.0748	14.84	286.33	23.6	144	22	992	194	14	31	80	8.97
14.4	0.0748	14.79	286.52	23.6	144	22	992	194	14	31	80	8.97
14.2	0.0748	14.84	285.35	23.5	144	22	992	195	14	31	80	8.97
14.2	0.0748	14.84	287.11	23.5	144	22	992	194	14	31	81	8.97
14.2	0.0748	14.79	286.33	23.5	144	22	992	194	14	31	81	8.98
14.3	0.0748	14.79	285.16	23.5	144	22	992	194	14	31	81	8.97
14.3	0.0748	14.79	285.35	23.5	144	22	992	194	14	31	81	8.97
14.3	0.0748	14.75	285.94	23.5	144	22	992	194	14	31	81	8.97
14.3	0.0748	14.84	286.13	23.5	144	22	992	194	14	31	73	8.97
14.2	0.0748	14.79	286.13	23.5	144	22	992	195	14	31	78	8.97
14.2	0.0748	14.84	285.94	23.5	144	22	992	195	14	31	78	8.97
14.2	0.0748	14.79	285.74	23.5	144	22	992	193	14	31	80	8.97
14.4	0.0748	14.84	286.33	23.5	144	22	992	195	14	31	81	8.98
14.4	0.0748	14.79	286.13	23.5	144	22	992	194	15	31	81	8.97
14.4	0.0748	14.79	285.94	23.5	144	22	992	194	15	31	81	8.97
14.1	0.0748	14.79	285.74	23.5	144	22	992	194	15	31	81	8.97

14.4	0.0748	14.79	285.94	23.5	144	22	992	194	15	32	81	8.98
14.2	0.0748	14.79	286.13	23.5	144	22	992	195	14	32	81	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	194	14	31	82	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	194	14	31	82	8.97
14.5	0.0748	14.79	285.35	23.5	144	23	992	194	14	31	82	8.97
14.5	0.0748	14.79	286.52	23.5	144	23	992	194	14	31	82	8.97
14.6	0.0484	14.79	285.74	23.5	144	23	992	195	15	32	66	8.97
14.6	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	66	8.97
14.6	0.0748	14.79	286.33	23.5	144	23	992	195	15	32	66	8.98
14.7	0.0748	14.79	285.35	23.5	144	23	992	195	15	31	92	8.97
14.7	0.0748	14.79	286.52	23.5	144	23	992	195	15	31	92	8.97
14.7	0.0748	14.79	286.52	23.5	144	23	992	195	15	31	92	8.97
14.6	0.0748	14.75	285.94	23.5	144	23	992	195	15	30	94	8.98
14.6	0.0748	14.79	285.94	23.5	144	23	992	195	15	30	94	8.97
14.6	0.0748	14.79	285.74	23.5	144	23	992	195	15	30	94	8.97
14.6	0.0748	14.84	285.55	23.5	144	23	992	195	15	30	94	8.97
14.6	0.0748	14.79	286.13	23.5	144	23	992	195	15	30	94	8.97
14.6	0.0748	14.79	286.13	23.5	144	23	992	193	15	28	60	8.97
14.6	0.0748	14.75	286.72	23.5	144	23	992	193	15	28	60	8.97

14.5	0.0748	14.75	285.94	23.5	144	23	992	195	15	29	81	8.98
14.5	0.0748	14.75	285.35	23.5	144	23	992	195	15	29	81	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	195	15	29	81	8.97
14.5	0.0748	14.79	285.94	23.5	144	23	992	195	15	29	81	8.97
14.5	0.0748	14.75	286.13	23.5	144	23	992	195	15	29	81	8.98
14.5	0.0748	14.75	286.13	23.5	144	23	992	195	15	29	81	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	195	15	29	81	8.97
14.5	0.0748	14.75	286.13	23.5	144	23	992	194	15	31	83	8.97
14.5	0.0484	14.79	285.94	23.5	144	23	992	194	15	31	83	8.98
14.5	0.0748	14.79	285.94	23.5	144	23	992	194	15	31	83	8.98
14.3	0.0748	14.75	285.94	23.5	144	23	992	195	15	32	70	8.97
14.3	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	70	8.97
14.4	0.0748	14.79	286.91	23.5	144	23	992	194	15	31	81	8.97
14.4	0.0748	14.79	286.33	23.5	144	23	992	194	15	31	81	8.97
14.4	0.0748	14.75	285.94	23.5	144	23	992	194	15	31	81	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	195	15	32	83	8.98
14.5	0.0748	14.79	286.52	23.5	144	23	992	195	15	32	83	8.98
14.5	0.0748	14.75	285.94	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.79	286.13	23.5	144	23	992	195	15	32	83	8.98

14.5	0.0748	14.79	285.35	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.79	285.94	23.5	144	23	992	195	15	32	83	8.98
14.5	0.0484	14.75	285.74	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.79	285.94	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.75	285.94	23.5	144	23	992	195	15	32	83	8.98
14.5	0.0748	14.75	285.16	23.5	144	23	992	195	15	32	81	8.97
14.5	0.0748	14.79	285.94	23.5	144	23	992	195	15	32	81	8.98
14.5	0.0748	14.79	285.55	23.5	144	23	992	195	15	32	81	8.98
14.5	0.0748	14.75	285.94	23.5	144	23	992	195	15	32	81	8.98
14.4	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.75	285.35	23.5	144	23	992	194	15	32	83	8.97
14.5	0.0748	14.79	285.74	23.5	144	23	992	194	15	32	83	8.98
14.5	0.0748	14.75	285.16	23.5	144	23	992	194	15	32	83	8.97
14.5	0.0748	14.75	286.13	23.5	144	23	992	194	15	32	83	8.97
14.5	0.0748	14.84	285.74	23.5	144	23	992	194	15	32	83	8.98
14.5	0.0748	14.79	285.74	23.5	144	23	992	194	15	32	83	8.97
14.5	0.0748	14.75	285.94	23.5	144	23	992	194	15	32	83	8.98
14.2	0.0748	14.75	286.13	23.5	144	23	992	195	15	32	77	8.97
14.5	0.0748	14.75	286.13	23.5	144	23	992	195	15	32	81	8.97

14.5	0.0748	14.79	286.33	23.5	144	23	992	195	15	32	83	8.97
14.5	0.0748	14.79	286.33	23.5	144	23	992	195	15	32	83	8.98
14.5	0.0748	14.79	285.94	23.5	144	23	992	195	15	32	89	8.97
14.5	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	91	8.98
14.5	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	91	8.97
14.5	0.0748	14.75	285.94	23.5	144	23	992	195	15	32	91	8.97
14.5	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	91	8.98
14.5	0.0748	14.79	285.74	23.5	144	23	992	195	15	32	91	8.97
14.6	0.0748	14.79	285.16	23.5	143	24	992	195	15	30	97	0.13
14.6	0.0748	14.75	284.96	23.5	143	24	992	195	15	30	97	0.13
14.8	0.0748	14.75	285.55	23.5	144	24	992	195	15	30	88	8.97
14.8	0.0748	14.79	285.94	23.5	144	24	992	195	15	30	88	8.98
14.6	0.0748	14.79	285.74	23.5	144	24	992	192	15	29	91	8.97
14.6	0.0748	14.75	284.96	23.5	144	24	992	192	15	29	91	8.98
14.8	0.0748	14.79	286.13	23.5	144	24	992	191	15	29	86	8.97
14.8	0.0748	14.79	284.96	23.5	144	24	992	191	15	29	86	8.98
14.4	0.0748	14.75	285.55	23.6	144	24	992	192	15	30	84	8.97
14.4	0.0748	14.79	284.77	23.6	144	24	992	192	15	30	84	8.97
14.6	0.0748	14.79	285.94	23.6	144	24	992	192	15	31	86	8.97

14.6	0.0748	14.75	285.94	23.6	144	24	992	192	15	31	86	8.98
14.6	0.0748	14.75	285.94	23.6	144	24	992	192	15	31	86	8.98
14.6	0.0748	14.75	284.96	23.6	144	24	992	192	15	31	86	8.97
14.6	0.0748	14.79	285.94	23.6	144	24	992	192	15	31	86	8.97
14.6	0.0748	14.75	285.94	23.6	144	24	992	192	15	31	86	8.97
14.6	0.0748	14.75	286.33	23.6	144	24	992	192	15	31	86	8.98
14.4	0.0748	14.70	285.35	23.6	144	24	992	195	15	32	82	8.97
14.4	0.0748	14.79	285.74	23.6	144	24	992	195	15	32	82	8.97
14.4	0.0748	14.75	285.55	23.6	144	24	992	195	15	32	82	8.97
14.8	0.0748	14.70	285.55	23.6	144	24	992	195	15	32	84	8.98
14.8	0.0748	14.79	285.55	23.6	144	24	992	195	15	32	84	8.97
14.8	0.0748	14.75	285.74	23.6	144	24	992	195	15	32	84	8.97
14.8	0.0748	14.79	285.35	23.6	144	24	992	195	15	32	84	8.97
14.8	0.0748	14.75	285.55	23.6	144	24	992	194	15	32	86	8.97
14.6	0.0748	14.75	285.55	23.5	144	24	992	195	15	32	85	8.97
14.6	0.0748	14.70	285.55	23.5	144	24	992	195	15	32	85	8.98
14.6	0.0748	14.75	286.13	23.5	144	24	992	195	15	32	85	8.97
14.6	0.0748	14.75	286.52	23.5	144	24	992	195	15	32	85	8.97
14.5	0.0748	14.75	286.13	23.5	144	24	992	193	15	32	83	8.97

14.5	0.0748	14.75	285.55	23.5	144	24	992	193	15	32	83	8.97
14.5	0.0748	14.70	285.74	23.5	144	24	992	193	15	32	83	8.97
14.5	0.0748	14.75	284.38	23.5	144	24	992	193	15	32	83	8.97
14.5	0.0748	14.75	285.35	23.6	144	24	992	195	15	32	84	8.97
14.5	0.0748	14.75	285.16	23.6	144	24	992	195	15	32	84	8.97
14.5	0.0748	14.70	286.33	23.6	144	24	992	195	15	32	84	8.98
14.7	0.0748	14.75	285.35	23.6	144	24	992	194	15	32	84	8.98
14.7	0.0748	14.75	285.94	23.6	144	24	992	194	15	32	84	8.97
14.7	-0.0044	14.75	286.13	23.6	144	24	992	194	15	32	84	8.97
14.7	-0.0044	14.75	285.55	23.6	144	24	992	194	15	32	84	8.97
14.7	-0.0044	14.75	285.55	23.6	144	24	992	194	15	32	84	8.98
14.7	-0.0044	14.70	285.74	23.6	144	24	992	194	15	32	84	8.97
14.7	-0.0044	14.70	285.74	23.6	144	24	992	194	15	32	84	8.97
14.7	-0.0044	14.75	285.55	23.6	144	24	992	194	15	32	81	8.97
14.7	-0.0044	14.65	284.96	23.6	144	24	992	194	15	32	81	8.97
14.5	-0.0044	14.65	285.35	23.6	144	24	992	194	15	32	85	8.97
14.4	-0.0044	14.70	286.13	23.6	144	24	992	195	15	32	84	8.97
14.5	-0.0044	14.70	285.55	23.6	144	24	992	195	15	32	84	8.97
14.5	-0.0044	14.75	285.16	23.6	144	24	992	195	15	32	84	8.98

14.5	-0.0044	14.79	285.74	23.6	144	24	992	195	15	32	84	8.98
14.5	-0.0044	14.75	285.74	23.6	144	24	992	195	15	32	84	8.97
14.7	-0.0044	14.70	285.55	23.5	143	24	992	195	15	32	97	0.13
14.7	-0.0044	14.75	285.94	23.5	143	24	992	195	15	32	97	0.12
14.7	-0.0044	14.75	285.35	23.5	143	24	992	195	15	32	97	0.13
14.7	-0.0044	14.75	285.55	23.5	143	24	992	195	15	32	97	0.12
14.6	-0.0044	14.79	285.55	23.6	144	24	992	194	15	30	96	8.97
14.6	-0.0044	14.75	285.55	23.6	144	24	992	194	15	30	97	8.98
14.6	-0.0044	14.79	285.55	23.6	144	24	992	194	15	30	97	8.97
14.5	-0.0044	14.79	285.55	23.6	144	24	992	192	15	30	95	8.97
14.5	-0.0044	14.79	284.57	23.6	144	24	992	192	15	30	95	8.97
14.5	-0.0044	14.75	285.94	23.6	144	24	992	192	15	30	95	8.97
14.4	-0.0044	14.75	285.55	23.6	144	24	992	191	15	30	87	8.97
14.4	0.0748	14.70	285.35	23.6	144	24	992	191	15	30	87	8.97
14.4	0.0748	14.79	285.35	23.6	144	24	992	191	15	30	87	8.97
14.4	0.0748	14.75	285.55	23.6	144	24	992	191	15	30	87	8.98
14.4	0.0748	14.75	285.16	23.6	144	24	992	191	15	30	87	8.97
14.4	0.0748	14.75	285.35	23.6	144	24	992	191	15	30	87	8.97
14.4	0.0748	14.75	285.35	23.6	144	24	992	191	15	30	87	8.97

14.4	0.0748	14.79	285.35	23.6	144	24	992	191	15	30	87	8.97
14.6	0.0748	14.75	285.55	23.6	144	24	992	194	15	32	86	8.97
14.6	0.0748	14.79	285.35	23.6	144	24	992	194	15	32	86	8.97
14.6	0.0748	14.75	286.52	23.6	144	24	992	194	15	32	86	8.97
14.5	0.0748	14.75	284.38	23.6	144	24	992	195	15	32	86	8.97
14.4	0.0748	14.79	285.35	23.6	144	24	992	195	15	32	86	8.97
14.4	0.0748	14.79	284.96	23.6	144	24	992	195	15	32	86	8.97
14.4	0.0748	14.79	285.35	23.6	144	24	992	195	15	32	86	8.97
14.6	0.0748	14.75	284.38	23.6	144	24	992	194	15	32	86	8.97
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	33	86	8.97
14.4	0.0748	14.75	285.74	23.6	144	24	992	195	15	33	86	8.97
14.4	0.0748	14.79	285.35	23.6	144	24	992	195	15	33	86	8.97
14.4	0.0748	14.79	285.35	23.6	144	24	992	195	15	33	81	8.97
14.4	0.0748	14.75	285.74	23.6	144	24	992	195	15	33	81	8.97
14.4	0.0748	14.75	285.94	23.6	144	24	992	195	15	33	81	8.98
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	33	81	8.97
14.5	0.0748	14.79	285.16	23.6	144	24	992	195	15	33	86	8.97
14.5	0.0748	14.79	285.35	23.6	144	24	992	195	15	33	86	8.98
14.5	0.0748	14.75	286.33	23.6	144	24	992	195	15	32	86	8.98

14.6	0.0748	14.70	285.35	23.6	144	24	992	194	15	32	86	8.97
14.5	0.0748	14.75	285.35	23.6	144	24	992	195	15	33	86	8.97
14.5	0.0748	14.75	285.55	23.6	144	24	992	195	15	32	86	8.97
14.3	0.0748	14.75	285.74	23.6	144	24	992	195	15	33	86	8.97
14.6	0.0748	14.75	285.16	23.6	144	24	992	194	15	33	73	8.98
14.6	0.0748	14.79	284.96	23.6	144	24	992	194	15	33	73	8.98
14.5	0.0748	14.70	285.35	23.6	144	24	992	194	15	32	83	8.97
14.5	0.0748	14.70	285.35	23.6	144	24	992	194	15	32	83	8.97
14.6	0.0748	14.75	285.35	23.6	144	24	992	195	15	32	86	8.97
14.6	0.0748	14.75	285.55	23.6	144	24	992	195	15	32	86	8.97
14.6	0.0748	14.79	285.74	23.6	144	24	992	195	15	32	86	8.97
14.6	0.0748	14.75	285.74	23.6	144	24	992	195	15	32	86	8.98
14.4	0.0748	14.75	284.77	23.6	144	24	992	195	15	33	86	8.98
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	33	86	8.97
14.6	0.0748	14.70	285.74	23.6	143	24	992	195	15	33	98	0.13
14.6	0.0748	14.70	285.16	23.6	143	24	992	195	15	33	98	0.13
14.6	0.0748	14.70	285.35	23.6	143	24	992	195	15	33	98	0.12
14.6	0.0748	14.75	285.74	23.6	143	24	992	195	15	33	98	0.13
14.4	0.0748	14.70	284.77	23.6	144	24	992	195	15	31	99	8.98

14.4	0.0748	14.70	286.13	23.6	144	24	992	195	15	30	99	8.98
14.4	0.0748	14.75	284.77	23.6	144	24	992	195	15	30	99	8.97
14.4	0.1012	14.75	284.57	23.6	144	24	992	195	15	30	99	8.97
14.4	0.0748	14.75	284.77	23.6	144	24	992	195	15	30	99	8.97
14.7	0.0748	14.75	285.35	23.6	144	24	992	190	15	30	88	8.98
14.6	0.0748	14.75	285.35	23.6	144	24	992	191	15	30	88	8.97
14.7	0.0748	14.75	285.55	23.6	144	24	992	192	15	31	88	8.97
14.6	0.0748	14.75	284.57	23.6	144	24	992	191	15	32	88	8.97
14.6	0.0748	14.75	285.35	23.6	144	24	992	191	15	32	88	8.97
14.6	0.0748	14.75	285.35	23.6	144	24	992	191	15	32	88	8.98
14.6	0.0748	14.70	284.96	23.6	144	24	992	191	15	32	88	8.97
14.6	0.0748	14.70	284.77	23.6	144	24	992	191	15	32	88	8.98
14.4	0.0748	14.75	285.35	23.6	144	24	992	195	15	33	88	8.97
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	33	88	8.97
14.4	0.0748	14.65	284.38	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.75	285.35	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.70	285.16	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.75	285.35	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.65	285.35	23.6	144	24	992	195	15	33	88	8.97

14.6	0.0748	14.70	285.55	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.75	285.55	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.75	285.55	23.6	144	24	992	195	15	33	84	8.97
14.5	0.0748	14.70	284.96	23.6	144	24	992	194	15	32	85	8.97
14.5	0.0748	14.70	285.35	23.6	144	24	992	194	15	32	85	8.98
14.7	0.0748	14.75	285.16	23.6	144	24	992	195	15	32	86	8.97
14.6	0.0748	14.75	284.96	23.6	144	24	992	195	15	32	88	8.97
14.6	0.0748	14.75	284.77	23.6	144	24	992	195	15	33	87	8.97
14.6	0.1012	14.70	285.16	23.6	144	24	992	195	15	33	87	8.97
14.5	0.0748	14.65	284.18	23.6	144	24	992	195	15	32	87	8.97
14.6	0.0748	14.75	284.96	23.6	144	24	992	195	15	32	87	8.97
14.4	0.0748	14.70	285.55	23.6	144	24	992	195	15	33	88	8.97
14.4	0.0748	14.70	284.96	23.6	144	24	992	195	15	32	87	8.98
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	32	88	8.97
14.3	0.0748	14.79	285.35	23.6	144	24	992	194	15	33	88	8.97
14.6	0.0748	14.75	285.16	23.6	144	24	992	195	15	33	88	8.98
14.3	0.0748	14.70	284.96	23.6	144	24	992	195	15	33	88	8.98
14.3	0.0748	14.70	285.74	23.6	144	24	992	195	15	33	88	8.97
14.3	0.0748	14.70	284.38	23.6	144	24	992	195	15	33	88	8.97

14.5	0.0748	14.70	284.96	23.6	144	24	992	195	15	32	75	8.98
14.4	0.0748	14.75	284.77	23.6	144	24	992	195	15	33	79	8.97
14.7	0.0748	14.70	285.55	23.6	144	24	992	195	15	33	83	8.97
14.6	0.0748	14.75	285.16	23.7	144	24	992	194	15	32	85	8.97
14.3	0.0748	14.75	284.96	23.6	144	24	992	195	15	33	86	8.97
14.3	0.0748	14.75	284.96	23.6	144	24	992	195	15	33	86	8.97
14.3	0.0748	14.75	284.96	23.6	144	24	992	195	15	33	86	8.97
14.3	0.0748	14.75	284.38	23.6	144	24	992	195	15	33	86	8.97
14.4	0.0748	14.70	285.16	23.6	144	24	992	195	15	33	88	8.97
14.4	0.0748	14.75	284.96	23.6	144	24	992	195	15	33	88	8.97
14.6	0.0748	14.75	284.77	23.6	144	24	992	196	15	32	90	8.97
14.6	0.0748	14.75	284.96	23.6	144	24	992	196	15	32	90	8.97
14.7	0.0748	14.70	284.96	23.6	143	24	992	195	15	33	100	0.13
14.5	0.0748	14.70	284.96	23.6	144	24	992	195	15	32	91	8.97
14.3	0.0748	14.75	284.77	23.6	144	24	992	195	15	32	97	8.97
14.4	0.0748	14.75	285.16	23.6	144	24	992	195	15	32	97	8.97
14.4	0.0748	14.75	284.57	23.6	144	24	992	195	15	32	97	8.97
14.4	0.0748	14.75	285.35	23.6	144	24	992	195	15	32	97	8.97
14.6	0.0484	14.75	284.96	23.6	144	24	992	195	15	30	100	8.98

14.4	0.0748	14.75	284.57	23.6	144	24	992	196	15	30	101	8.97
14.4	0.0748	14.75	284.96	23.6	144	24	992	196	15	30	101	8.98
14.6	0.0748	14.75	285.74	23.7	144	24	992	192	15	30	99	8.97
14.5	0.0748	14.70	284.77	23.6	144	24	992	192	15	30	94	8.97
14.5	0.0748	14.75	285.35	23.6	144	24	992	192	15	30	94	8.97
14.5	0.2596	14.70	284.57	23.6	144	24	992	192	15	30	94	8.97
14.5	0.0748	14.75	284.96	23.6	144	24	992	192	15	30	94	8.97
14.5	0.0748	14.75	285.16	23.6	144	24	992	192	15	30	94	8.97
14.6	0.0748	14.70	284.77	23.7	144	24	992	184	15	32	72	8.97
14.5	0.0748	14.70	284.96	23.6	144	24	992	195	15	32	66	8.97
14.5	0.0748	14.70	285.55	23.6	144	24	992	195	15	32	66	8.97
14.3	0.0748	14.70	284.57	23.6	144	24	992	195	15	32	86	8.97
14.4	0.0748	14.70	284.38	23.6	144	24	992	195	15	32	87	8.98
14.4	0.0748	14.75	285.35	23.6	144	24	992	195	15	32	87	8.97
14.7	0.0748	14.70	284.77	23.7	144	24	992	195	15	32	88	8.97
14.6	0.0748	14.70	284.18	23.7	144	24	992	194	15	32	89	8.97
14.6	0.0748	14.75	284.77	23.7	144	24	992	194	15	32	89	8.97
14.5	0.1012	14.79	284.77	23.7	144	24	992	195	15	32	89	8.98
14.5	0.0748	14.75	285.16	23.7	144	24	992	195	15	32	89	8.97

14.5	0.0748	14.75	284.96	23.7	144	24	992	195	15	33	89	8.97
14.3	0.0748	14.70	284.77	23.6	144	24	992	195	15	33	89	8.97
14.4	0.0748	14.75	284.57	23.6	144	24	992	195	15	33	89	8.97
14.6	0.0748	14.75	284.57	23.6	144	24	992	195	15	32	89	8.97
14.6	0.0748	14.70	284.18	23.6	144	24	992	195	15	32	89	8.97
14.4	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	81	8.97
14.5	0.0748	14.75	284.96	23.7	144	24	992	195	15	33	86	8.97
14.4	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	87	8.97
14.5	0.0748	14.70	284.38	23.7	144	24	992	195	15	33	88	8.97
14.5	0.0748	14.75	284.18	23.7	144	24	992	195	15	33	88	8.98
14.3	0.0748	14.70	284.77	23.7	144	24	992	195	15	32	88	8.97
14.3	0.0748	14.70	284.77	23.6	144	24	992	195	15	33	88	8.97
14.4	0.0748	14.70	284.77	23.6	144	24	992	195	15	32	89	8.97
14.4	0.0748	14.70	283.79	23.6	144	24	992	195	15	32	89	8.97
14.4	0.0748	14.70	284.77	23.6	144	24	992	195	15	32	89	8.97
14.3	0.0748	14.75	284.77	23.7	144	24	992	189	15	33	70	8.97
14.6	0.0748	14.70	283.40	23.7	144	24	992	192	15	33	66	8.97
14.6	0.0748	14.75	285.16	23.7	144	24	992	192	15	33	66	8.97
14.6	0.0748	14.75	284.57	23.7	144	24	992	195	15	33	80	8.98

14.6	0.0748	14.65	284.77	23.7	144	24	992	195	15	33	84	8.97
14.6	0.0748	14.70	285.16	23.7	144	24	992	195	15	33	84	8.97
14.5	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	88	8.98
14.5	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	89	8.97
14.3	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	88	8.98
14.3	0.0748	14.75	284.96	23.7	144	24	992	195	15	33	88	8.98
14.6	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	89	8.97
14.7	0.0748	14.75	284.77	23.7	144	24	992	195	15	33	89	8.98
14.7	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	89	8.98
14.7	0.0748	14.75	284.38	23.7	144	24	992	195	15	33	89	8.97
14.6	0.0748	14.70	284.96	23.6	143	24	992	195	15	33	100	0.12
14.6	0.0748	14.75	284.77	23.7	144	24	992	196	15	32	86	8.98
14.6	0.0748	14.75	284.77	23.7	144	24	992	196	15	32	86	8.98
14.6	0.0748	14.75	284.77	23.7	144	24	992	196	15	32	86	8.97
14.6	0.0748	14.75	284.18	23.7	144	24	992	195	15	31	100	8.98
14.6	0.0748	14.75	284.96	23.7	144	24	992	195	15	31	100	8.97
14.6	0.0748	14.70	284.38	23.7	144	24	992	195	15	31	100	8.98
14.6	0.0748	14.75	284.57	23.7	144	24	992	195	15	31	100	8.98
14.6	0.0748	14.70	284.77	23.7	144	24	992	195	15	31	100	8.98

14.6	0.0748	14.70	285.16	23.7	144	24	992	195	15	31	100	8.98
14.7	0.0748	14.70	284.77	23.7	144	24	992	191	15	30	92	8.97
14.7	0.0748	14.75	284.38	23.7	144	24	992	191	15	30	92	8.97
14.4	0.0748	14.75	284.77	23.7	144	24	992	191	15	30	90	8.98
14.4	0.0748	14.75	284.57	23.7	144	24	992	191	15	30	90	8.97
14.6	0.0748	14.70	285.35	23.7	144	24	992	182	15	31	76	8.98
14.7	0.0748	14.75	284.18	23.7	144	24	992	195	15	32	78	8.98
14.3	0.0748	14.75	284.57	23.7	144	24	992	195	15	32	83	8.97
14.3	0.0748	14.70	283.98	23.7	144	24	992	195	15	32	83	8.97
14.6	0.0748	14.70	284.77	23.7	144	24	992	194	15	32	89	8.97
14.5	0.0748	14.75	285.35	23.7	144	24	992	195	15	32	89	8.97
14.5	0.0748	14.75	284.57	23.7	144	24	992	195	15	33	89	8.97
14.5	0.0748	14.70	284.77	23.7	144	24	992	195	15	33	89	8.97
14.6	0.0748	14.75	284.77	23.7	144	24	992	195	15	33	90	8.97
14.3	0.0748	14.70	284.57	23.7	144	24	992	195	15	32	90	8.97
14.3	0.0748	14.75	284.96	23.7	144	24	992	195	15	32	90	8.97
14.3	0.0748	14.70	284.77	23.7	144	24	992	195	15	32	90	8.97
14.3	0.2596	14.75	285.35	23.7	144	24	992	195	15	32	90	8.97
14.3	-0.0044	14.70	284.77	23.7	144	24	992	195	15	32	90	8.97

14.3	-0.0044	14.65	222.27	23.7	144	24	992	190	15	32	76	8.98
14.3	-0.0044	14.70	279.69	23.7	144	24	992	190	15	32	76	8.97
14.3	-0.0044	14.70	280.27	23.7	144	24	992	190	15	32	76	8.97
14.6	-0.0044	14.70	280.86	23.7	144	24	992	195	15	32	88	8.97
14.6	-0.0044	14.70	279.69	23.7	144	24	992	195	15	32	88	8.97
14.6	-0.0044	14.75	279.30	23.7	144	24	992	195	15	32	88	8.98
14.6	-0.0044	14.70	279.49	23.7	144	24	992	195	15	32	88	8.97
14.3	-0.0044	14.65	278.91	23.7	144	24	992	195	15	32	89	8.98
14.3	-0.0044	14.70	280.66	23.7	144	24	992	195	15	32	89	8.98
14.3	-0.0044	14.70	280.47	23.7	144	24	992	195	15	32	89	8.97
14.6	-0.0044	14.70	280.08	23.7	144	24	992	195	15	33	89	8.97
14.6	-0.0044	14.75	280.47	23.7	144	24	992	195	15	33	89	8.97
14.6	-0.0044	14.75	280.47	23.7	144	24	992	195	15	33	89	8.98
14.5	-0.0044	14.75	279.88	23.7	144	24	992	195	15	33	87	8.97
14.3	-0.0044	14.70	279.69	23.7	144	24	992	195	15	33	89	8.97
14.3	-0.0044	14.70	280.47	23.7	144	24	992	195	15	33	89	8.97
14.4	-0.0044	14.75	280.27	23.7	144	24	992	195	15	33	89	8.98
14.4	-0.0044	14.70	280.08	23.7	144	24	992	195	15	33	89	8.97
14.4	-0.0044	14.70	279.10	23.7	144	24	992	195	15	33	89	8.97

14.5	-0.0044	14.75	280.08	23.7	144	24	992	195	15	33	89	8.97
14.5	-0.0044	14.70	279.69	23.7	144	24	992	195	15	33	89	8.97
14.5	-0.0044	14.70	279.88	23.7	144	24	992	196	15	33	91	8.98
14.5	-0.0044	14.79	279.88	23.7	144	24	992	196	15	33	91	8.97
14.5	-0.0044	14.75	280.47	23.7	144	24	992	196	15	33	91	8.97
14.5	-0.0044	14.70	280.27	23.7	144	24	992	196	15	33	91	8.97
14.5	-0.0044	14.70	280.08	23.7	144	24	992	195	15	32	100	8.97
14.4	-0.0044	14.70	280.47	23.7	144	24	992	195	15	31	102	8.97
14.4	-0.0044	14.70	280.27	23.7	144	24	992	196	15	30	103	8.97
14.4	-0.0044	14.70	280.27	23.7	144	24	992	195	15	31	103	8.97
14.3	0.0748	14.70	279.88	23.7	144	24	992	196	15	30	104	8.97
14.3	0.0748	14.70	280.27	23.7	144	24	992	196	15	30	104	8.97
14.3	0.0748	14.75	280.27	23.7	144	24	992	196	15	30	104	8.97
14.3	0.0748	14.70	280.08	23.7	144	24	992	196	15	30	104	8.98
14.3	0.0748	14.75	279.69	23.7	144	24	992	196	15	30	104	8.98
14.3	0.0748	14.70	280.66	23.7	144	24	992	196	15	30	104	8.97
14.5	0.0748	14.70	280.08	23.7	144	24	992	191	15	31	91	8.97
14.5	0.0748	14.70	279.30	23.7	144	24	992	191	15	31	91	8.97
14.3	0.0748	14.70	280.47	23.7	144	24	992	195	15	32	84	8.98

14.7	0.0748	14.70	280.08	23.7	144	24	992	195	15	32	89	8.97
14.5	0.0748	14.70	280.27	23.7	144	24	992	195	15	33	89	8.97
14.5	0.0748	14.70	280.86	23.7	144	24	992	195	15	33	89	8.98
14.4	0.0748	14.70	279.10	23.7	144	24	992	195	15	32	90	8.97
14.4	0.0748	14.70	280.27	23.7	144	24	992	195	15	32	90	8.97
14.5	0.0748	14.70	280.08	23.7	144	24	992	195	15	32	91	8.97
14.5	0.0748	14.70	279.69	23.7	144	24	992	195	15	32	91	8.97
14.5	0.0748	14.65	280.08	23.7	144	24	992	195	15	32	91	8.98
14.3	0.0748	14.70	280.66	23.7	144	24	992	196	15	33	91	8.97
14.5	0.0748	14.70	280.66	23.7	144	24	992	195	15	33	90	8.98
14.5	0.0748	14.70	280.27	23.7	144	24	992	195	15	33	90	8.98
14.5	0.0748	14.65	280.86	23.7	144	24	992	195	15	33	90	8.97
14.5	0.0748	14.75	280.27	23.7	144	24	992	194	15	32	88	8.98
14.5	0.0748	14.70	279.69	23.7	144	24	992	194	15	32	88	8.97
14.5	0.0748	14.70	280.08	23.7	144	24	992	194	15	32	88	8.98
14.5	0.0748	14.65	279.88	23.7	144	24	992	194	15	32	88	8.97
14.5	0.0748	14.79	280.08	23.7	144	24	992	194	15	32	88	8.98
14.5	0.0748	14.70	280.66	23.7	144	24	992	195	15	32	90	8.97
14.5	0.0748	14.70	280.47	23.7	144	24	992	195	15	32	90	8.97

14.3	0.0748	14.70	280.08	23.7	144	24	992	195	15	32	90	8.97
14.4	0.0748	14.75	279.69	23.7	144	24	992	195	15	32	90	8.97
14.4	0.0748	14.65	279.88	23.7	144	24	992	195	15	32	90	8.97
14.4	0.0748	14.65	280.08	23.7	144	24	992	195	15	32	90	8.98
14.4	0.0748	14.70	280.08	23.7	144	24	992	195	15	32	90	8.97
14.6	0.0748	14.70	280.86	23.7	144	24	992	195	15	33	86	8.97
14.3	0.0748	14.65	279.88	23.7	144	24	992	195	15	33	87	8.98
14.3	0.0748	14.70	279.88	23.7	144	24	992	195	15	33	87	8.97
14.3	0.0748	14.65	279.88	23.7	144	24	992	195	15	33	87	8.97
14.3	0.0748	14.70	280.86	23.7	144	24	992	195	15	33	87	8.97
14.3	0.0748	14.70	280.27	23.7	144	24	992	194	15	33	91	8.97
14.3	0.0748	14.70	280.08	23.7	144	24	992	195	15	33	91	8.97
14.3	0.0748	14.70	280.27	23.7	144	24	992	195	15	33	91	8.97
14.6	0.0748	14.70	280.27	23.7	144	24	992	195	15	33	91	8.98
14.3	0.0748	14.70	280.08	23.7	144	24	992	195	15	33	91	8.97
14.3	0.0748	14.65	280.47	23.7	144	24	992	195	15	33	91	8.98
14.3	0.0748	14.70	279.69	23.7	144	24	992	195	15	33	91	8.97
14.6	0.0748	14.70	280.27	23.7	144	24	992	195	15	32	81	8.97
14.6	0.0748	14.70	279.88	23.7	144	24	992	195	15	32	81	8.97

14.6	0.0748	14.70	279.88	23.7	144	24	992	195	15	32	81	8.97
14.6	0.0748	14.70	280.08	23.7	144	24	992	195	15	32	81	8.98
14.6	0.0748	14.65	279.49	23.7	144	24	992	195	15	32	81	8.97
14.4	0.0748	14.65	279.69	23.7	144	24	992	195	15	30	104	8.98
14.4	0.0748	14.70	281.05	23.7	144	24	992	195	15	30	104	8.97
14.6	0.0748	14.65	280.08	23.7	144	24	992	192	15	30	101	8.97
14.6	0.0748	14.70	279.49	23.7	144	24	992	192	15	30	101	8.98
14.6	0.0748	14.70	279.49	23.7	144	24	992	192	15	30	101	8.97
14.6	0.0748	14.70	279.88	23.7	144	24	992	192	15	30	101	8.97
14.6	0.0748	14.70	279.88	23.7	144	24	992	192	15	30	101	8.97
14.6	0.0748	14.70	280.66	23.7	144	24	992	192	15	30	101	8.97
14.3	0.0748	14.70	280.47	23.7	144	24	992	195	15	32	78	8.97
14.4	0.0748	14.70	279.88	23.7	144	24	992	195	15	32	84	8.97
14.4	0.0748	14.70	279.69	23.7	144	24	992	195	15	32	84	8.97
14.3	0.0748	14.65	279.88	23.7	144	24	992	194	15	32	89	8.97
14.3	0.0748	14.70	279.88	23.7	144	24	992	194	15	32	89	8.97
14.5	0.0748	14.70	280.27	23.7	144	24	992	194	15	32	91	8.97
14.5	0.0748	14.75	280.08	23.7	144	24	992	194	15	32	91	8.97
14.5	0.0748	14.70	279.88	23.7	144	24	992	195	15	33	90	8.97

14.5	0.0748	14.70	280.47	23.7	144	24	992	195	15	33	90	8.97
14.5	0.0748	14.65	279.88	23.7	144	24	992	195	15	33	90	8.97
14.5	0.0748	14.65	279.10	23.7	144	24	992	195	15	33	90	8.97
14.5	0.0748	14.65	279.69	23.7	144	24	992	195	15	33	91	8.97
14.5	0.0748	14.70	286.91	23.7	144	24	992	195	15	33	91	8.97
14.3	0.0748	14.70	287.30	23.7	144	24	992	195	15	32	91	8.97
14.6	0.0748	14.65	286.91	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.70	287.50	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.70	287.70	23.8	144	24	992	195	15	33	80	8.98
14.6	0.0748	14.70	286.91	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.65	287.11	23.8	144	24	992	195	15	33	80	8.98
14.6	0.0748	14.65	286.91	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.65	286.91	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.65	287.11	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.65	286.91	23.8	144	24	992	195	15	33	80	8.97
14.6	0.0748	14.65	287.50	23.7	144	24	992	195	15	33	91	8.97
14.6	0.1012	14.70	287.11	23.7	144	24	992	195	15	33	91	8.97
14.6	0.0748	14.70	286.72	23.8	144	24	992	194	15	33	68	8.97
14.4	0.0748	14.65	287.11	23.8	144	24	992	194	14	33	83	8.97

14.4	0.0748	14.65	286.91	23.8	144	24	992	194	14	33	83	8.97
14.4	0.0748	14.65	286.91	23.8	144	24	992	194	14	33	83	8.97
14.4	0.0748	14.60	286.72	23.8	144	24	992	194	14	33	83	8.97
14.4	0.0748	14.65	287.50	23.8	144	24	992	194	14	33	83	8.97
14.4	0.0748	14.65	286.91	23.8	144	24	992	194	14	33	83	8.97
14.4	0.0748	14.70	286.91	23.8	144	24	992	194	14	33	83	8.97
14.5	0.0748	14.65	286.52	23.8	144	24	992	195	15	33	91	8.97
14.5	0.0748	14.65	286.91	23.8	144	24	992	195	15	33	91	8.97
14.3	0.0748	14.65	286.52	23.7	143	24	992	196	14	33	100	0.13
14.3	0.2332	14.70	286.91	23.7	143	24	992	196	14	33	100	0.12
14.3	-0.0044	14.65	287.11	23.7	143	24	992	196	14	33	100	0.13
14.5	-0.0044	14.65	287.30	23.8	144	24	992	195	15	32	102	8.97
14.5	-0.0044	14.70	286.91	23.8	144	24	992	195	15	32	102	8.98
14.4	-0.0044	14.65	286.91	23.8	144	24	992	195	15	31	104	8.97
14.6	-0.0044	14.70	286.72	23.7	144	24	992	195	15	30	105	8.97
14.6	-0.0044	14.65	286.33	23.7	144	24	992	195	15	30	105	8.97
14.6	-0.0044	14.65	286.72	23.7	144	24	992	195	15	30	105	8.97
14.6	-0.0044	14.65	286.72	23.7	144	24	992	195	15	30	105	8.97
14.6	-0.0044	14.65	287.11	23.7	144	24	992	195	15	30	105	8.97

14.6	-0.0044	14.65	286.91	23.7	144	24	992	195	15	30	105	8.97
14.3	-0.0044	14.65	286.91	23.7	144	24	992	191	15	30	92	8.97
14.3	-0.0044	14.65	286.91	23.7	144	24	992	191	15	30	92	8.97
14.3	-0.0044	14.65	286.72	23.7	144	24	992	191	15	30	92	8.97
14.4	-0.0044	14.65	287.11	23.8	144	24	992	195	15	32	84	8.97
14.4	-0.0044	14.65	286.13	23.8	144	24	992	195	15	32	84	8.97
14.4	-0.0044	14.70	286.52	23.8	144	24	992	195	15	32	91	8.97
14.3	-0.0044	14.65	286.13	23.8	144	24	992	195	15	32	91	8.97
14.5	-0.0044	14.70	287.11	23.8	144	24	992	195	15	32	91	8.97
14.5	-0.0044	14.70	286.33	23.8	144	24	992	195	15	32	91	8.97
14.5	-0.0044	14.70	286.72	23.8	144	24	992	195	15	32	91	8.97
14.2	-0.0044	14.65	286.52	23.8	144	24	992	195	15	33	91	8.97
14.4	-0.0044	14.70	286.52	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.70	286.72	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.70	286.52	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.70	286.72	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.70	286.52	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.70	286.72	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.65	286.52	23.8	144	24	992	195	15	33	92	8.98

14.5	-0.0044	14.65	286.52	23.8	144	24	992	195	15	33	91	8.98
14.5	-0.0044	14.65	286.72	23.8	144	24	992	195	15	33	91	8.97
14.5	-0.0044	14.70	286.33	23.8	144	24	992	195	15	33	91	8.97
14.5	-0.0044	14.70	286.33	23.8	144	24	992	195	15	33	91	8.97
14.5	-0.0044	14.65	286.72	23.8	144	24	992	195	15	33	91	8.97
14.5	-0.0044	14.65	286.91	23.8	144	24	992	195	15	33	91	8.97
14.3	-0.0044	14.65	285.74	23.7	144	24	992	195	15	33	92	8.97
14.3	-0.0044	14.65	286.33	23.7	144	24	992	195	15	33	92	8.97
14.3	0.1012	14.65	286.72	23.7	144	24	992	195	15	33	92	8.97
14.5	0.0748	14.65	285.94	23.8	144	24	992	195	15	33	84	8.97
14.5	0.0748	14.70	286.13	23.8	144	24	992	195	15	33	84	8.97
14.5	0.0748	14.65	285.94	23.7	144	24	992	195	15	33	91	8.97
14.5	0.0748	14.65	286.72	23.8	144	24	992	195	15	33	92	8.97
14.5	0.0748	14.65	286.33	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.65	286.33	23.8	144	24	992	194	15	33	92	8.98
14.4	0.0748	14.65	286.33	23.8	144	24	992	194	15	33	92	8.97
14.4	0.0748	14.65	285.94	23.8	144	24	992	194	15	33	92	8.97
14.4	0.0748	14.70	286.52	23.8	144	24	992	194	15	33	92	8.98
14.4	0.0748	14.70	286.33	23.8	144	24	992	194	15	33	92	8.97

14.4	0.0748	14.65	286.33	23.8	144	24	992	194	15	33	92	8.97
14.4	0.0748	14.65	286.33	23.8	144	24	992	194	15	33	92	8.97
14.4	0.0748	14.70	286.33	23.8	144	24	992	194	15	33	92	8.97
14.6	0.0748	14.65	286.52	23.7	144	24	992	195	15	31	105	8.97
14.6	0.0748	14.70	285.35	23.7	144	24	992	195	15	31	105	8.97
14.6	0.0748	14.65	287.11	23.7	144	24	992	195	15	31	105	8.97
14.6	0.0748	14.70	286.33	23.7	144	24	992	195	15	31	105	8.97
14.5	0.0748	14.65	285.16	23.8	144	24	992	193	14	30	105	8.97
14.5	0.0748	14.65	285.35	23.8	144	24	992	193	14	30	105	8.97
14.5	0.0748	14.65	285.94	23.8	144	24	992	193	14	30	105	8.97
14.5	0.0748	14.65	286.13	23.8	144	24	992	193	14	30	105	8.97
14.5	0.0748	14.65	286.13	23.8	144	24	992	193	14	30	105	8.97
14.4	0.0748	14.70	285.94	23.8	144	24	992	195	15	32	71	8.97
14.4	0.0748	14.65	285.74	23.8	144	24	992	195	15	32	71	8.97
14.4	0.0748	14.70	286.33	23.8	144	24	992	195	15	32	71	8.97
14.4	0.0748	14.60	286.13	23.8	144	24	992	195	15	32	71	8.97
14.4	0.0748	14.70	285.94	23.8	144	24	992	195	15	32	71	8.97
14.4	0.0748	14.70	285.74	23.8	144	24	992	195	15	32	71	8.97
14.6	0.0748	14.65	285.94	23.8	144	24	992	195	15	32	93	8.97

14.6	0.0748	14.65	286.13	23.8	144	24	992	195	15	32	93	8.97
14.5	0.0748	14.65	286.13	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.65	286.13	23.8	144	24	992	195	15	33	92	8.98
14.5	-0.0044	14.70	285.35	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.60	286.52	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.65	285.74	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.60	285.74	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.65	286.33	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.60	285.35	23.8	144	24	992	195	15	33	92	8.97
14.4	-0.0044	14.65	286.52	23.8	144	24	992	195	15	33	92	8.97
14.5	-0.0044	14.70	286.52	23.8	144	24	992	194	15	33	92	8.97
14.5	-0.0044	14.65	285.94	23.8	144	24	992	194	15	33	92	8.97
14.6	-0.0044	14.65	285.94	23.8	144	24	992	195	15	33	92	8.97
14.6	-0.0044	14.65	285.74	23.8	144	24	992	195	15	33	92	8.97
14.3	-0.0044	14.65	285.55	23.8	144	24	992	195	15	33	92	8.97
14.3	0.0748	14.65	286.13	23.8	144	24	992	195	15	33	92	8.97
14.6	0.0748	14.65	286.13	23.8	144	24	992	195	14	32	92	8.97
14.6	0.0748	14.65	286.72	23.8	144	24	992	195	14	32	92	8.97
14.6	0.0748	14.65	285.94	23.8	144	24	992	195	15	33	92	8.97

14.6	0.0748	14.65	285.35	23.8	144	24	992	195	15	33	92	8.97
14.6	0.0748	14.70	286.13	23.8	144	24	992	195	15	33	92	8.98
14.6	0.0748	14.65	285.94	23.8	144	24	992	195	15	33	92	8.97
14.6	0.0484	14.65	286.13	23.8	144	24	992	195	15	33	92	8.97
14.3	0.0748	14.70	286.13	23.8	144	24	992	195	15	33	92	8.97
14.3	0.0748	14.70	286.13	23.8	144	24	992	195	15	33	92	8.97
14.3	0.0748	14.70	286.13	23.8	144	24	992	195	15	33	92	8.97
14.3	0.0748	14.65	285.94	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.70	285.94	23.8	144	24	992	195	15	33	92	8.98
14.4	0.0748	14.70	285.94	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.65	285.74	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.70	286.91	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.70	286.33	23.8	144	24	992	195	15	33	92	8.97
14.4	0.0748	14.70	285.94	23.8	144	24	992	196	14	32	103	8.97
14.5	0.0748	14.65	286.13	23.8	144	24	992	195	14	32	104	8.97
14.5	0.0748	14.70	286.52	23.8	144	24	992	195	14	32	104	8.97
14.6	0.0748	14.65	285.94	23.8	144	24	992	195	14	30	106	8.97
14.4	0.0748	14.65	286.13	23.8	144	24	992	195	14	31	106	8.97
14.3	0.0748	14.65	285.35	23.8	144	24	992	195	14	31	107	8.97

14.3	0.0748	14.65	285.94	23.8	144	24	992	195	14	31	107	8.97
14.3	0.0748	14.65	285.74	23.8	144	24	992	195	14	31	107	8.97
14.4	0.0748	14.65	285.94	23.8	144	24	992	192	15	30	99	8.97
14.1	0.0748	14.65	285.94	23.8	144	23	992	191	14	30	95	8.97
14.1	0.0748	14.65	285.16	23.8	144	23	992	191	14	30	95	8.97
14.1	0.0748	14.70	285.94	23.8	144	23	992	191	14	30	95	8.97
14.4	0.0748	14.65	285.55	23.8	144	24	992	194	14	32	65	8.97
14.6	0.0748	14.65	285.94	23.8	144	24	992	195	14	32	80	8.97
14.4	0.0748	14.65	285.74	23.8	144	24	992	195	14	32	86	8.97
14.4	0.0748	14.70	285.35	23.8	144	24	992	195	14	32	86	8.97
14.4	0.0748	14.60	285.74	23.8	144	24	992	195	15	32	91	8.97
14.4	0.0748	14.65	285.16	23.8	144	24	992	195	15	32	91	8.97
14.4	0.0748	14.65	286.13	23.8	144	24	992	195	15	32	91	8.97
14.4	0.0748	14.70	285.74	23.8	144	24	992	195	15	32	91	8.97
14.4	0.0748	14.70	285.74	23.8	144	24	992	195	15	32	91	8.97
14.4	0.0748	14.65	285.94	23.8	144	24	992	195	15	32	91	8.98
14.4	0.0748	14.65	286.13	23.8	144	24	992	195	15	32	91	8.97
14.7	0.0748	14.65	286.13	23.8	144	24	992	185	15	33	86	8.97
14.7	0.0748	14.70	286.33	23.8	144	24	992	185	15	33	86	8.97

14.7	0.0748	14.65	286.33	23.8	144	24	992	185	15	33	86	8.97
14.7	0.0748	14.65	285.94	23.8	144	24	992	185	15	33	86	8.97
14.7	0.0748	14.65	285.74	23.8	144	24	992	185	15	33	86	8.97
14.7	0.0748	14.65	285.74	23.8	144	24	992	185	15	33	86	8.97
14.7	0.0748	14.65	285.94	23.8	144	24	992	185	15	33	86	8.97
14.4	0.0748	14.65	285.74	23.8	144	24	992	195	15	32	93	8.97
14.3	0.0748	14.65	285.74	23.8	144	24	992	195	15	33	93	8.97
14.5	0.0748	14.65	285.16	23.8	144	24	992	195	14	33	93	8.97
14.6	0.0748	14.65	284.96	23.8	144	24	992	195	15	33	93	8.97
14.4	0.0748	14.60	285.55	23.8	144	24	992	195	14	33	93	8.97
14.4	0.0748	14.65	285.94	23.8	144	24	992	195	14	33	93	8.97
14.4	0.0748	14.65	285.74	23.8	144	24	992	195	14	32	92	8.97
14.4	0.0748	14.60	284.96	23.8	144	24	992	195	14	32	92	8.97
14.4	0.0748	14.65	286.13	23.8	144	24	992	194	14	33	70	8.97
14.4	0.0748	14.60	284.96	23.8	144	24	992	194	14	32	81	8.97
14.4	0.0748	14.60	285.55	23.8	144	24	992	194	14	32	81	8.97
14.6	0.0748	14.65	284.77	23.8	144	24	992	195	14	33	91	8.97
14.3	0.0748	14.65	285.94	23.8	144	24	992	195	14	33	92	8.98
14.3	0.0748	14.65	285.94	23.8	144	24	992	195	14	33	92	8.97

14.3	0.0748	14.65	285.94	23.8	144	24	992	195	14	33	92	8.97
14.5	0.0748	14.65	284.96	23.8	144	24	992	195	14	33	94	8.97
14.5	0.0748	14.60	285.94	23.8	144	24	992	195	14	33	94	8.97
14.2	0.0748	14.70	285.94	23.8	144	23	992	195	14	33	94	8.97
14.2	0.0748	14.65	286.33	23.8	144	23	992	195	14	33	94	8.97
14	0.0748	14.65	285.35	23.8	143	23	992	195	15	33	97	0.13
14	0.0748	14.65	285.74	23.8	143	23	992	195	15	33	97	0.13
14.6	0.0748	14.65	285.55	23.8	143	24	992	195	14	33	106	0.13
14.6	0.0748	14.65	285.55	23.8	143	24	992	195	14	33	106	0.13
14.4	0.0748	14.65	285.55	23.8	144	24	992	195	14	32	96	8.97
14.4	0.0748	14.70	285.74	23.8	144	24	992	195	14	32	96	8.97
14.4	0.1012	14.65	285.35	23.8	144	24	992	195	14	32	96	8.98
14.6	0.0748	14.65	285.55	23.8	144	24	992	195	14	31	107	8.97
14.5	0.0748	14.65	285.55	23.8	144	24	992	195	14	30	106	8.97
14.5	0.0748	14.65	285.55	23.8	144	24	992	195	14	30	106	8.98
14.5	0.0748	14.65	286.13	23.8	144	24	992	195	14	30	106	8.98
14.7	0.0748	14.65	286.52	23.8	144	24	992	192	14	30	101	8.97
14.4	0.0748	14.65	286.13	23.8	144	24	992	191	14	30	98	8.98
14.3	0.0748	14.65	285.55	23.8	144	24	992	192	14	30	96	8.97

14.2	0.1012	14.65	285.74	23.8	144	23	992	191	14	30	96	8.97
14.2	0.0748	14.60	284.38	23.8	144	23	992	191	14	30	96	8.97
14.6	0.0748	14.70	285.35	23.8	144	24	992	192	14	31	95	8.98
14.1	0.0748	14.65	285.16	23.8	144	23	992	187	14	32	72	8.98
14.1	0.0748	14.65	286.33	23.8	144	23	992	187	14	32	72	8.97
14.1	0.0748	14.65	285.35	23.8	144	23	992	194	14	32	84	8.97
14.7	0.0748	14.65	285.94	23.8	144	24	992	195	14	32	84	8.97
14.7	0.0748	14.65	286.13	23.8	144	24	992	195	14	32	84	8.97
14.7	0.0748	14.65	285.55	23.8	144	24	992	195	14	32	84	8.97
14.2	0.0748	14.65	285.55	23.8	144	23	992	195	14	33	93	8.97
14.2	0.0748	14.65	285.74	23.8	144	23	992	195	14	33	93	8.97
14.3	0.0748	14.65	285.74	23.8	144	24	992	195	15	33	94	8.97
14.6	0.0748	14.65	285.55	23.8	144	24	992	195	15	32	94	8.97
14.6	0.0748	14.70	284.96	23.8	144	24	992	195	15	32	94	8.97
14.6	0.0748	14.65	285.35	23.8	144	24	992	195	15	32	94	8.98
14.6	0.0748	14.65	286.13	23.8	144	24	992	195	15	32	94	8.97
14.6	0.0748	14.65	285.55	23.8	144	24	992	195	15	32	94	8.97
14.1	0.0748	14.65	285.16	23.8	144	23	992	195	14	33	83	8.97
14	0.0748	14.60	285.74	23.8	144	23	992	195	14	33	89	8.97

14.2	0.0748	14.65	285.74	23.8	144	23	992	195	14	33	92	8.97
14.2	0.0748	14.65	285.55	23.8	144	23	992	195	14	33	92	8.98
14.2	0.0748	14.60	285.94	23.8	144	23	992	195	14	33	92	8.97
14.5	0.0748	14.60	285.35	23.8	144	24	992	195	15	33	93	8.98
14.5	0.0748	14.65	285.55	23.8	144	24	992	195	15	33	93	8.97
14.5	0.0748	14.65	285.55	23.8	144	24	992	195	15	33	93	8.97
14.6	0.0748	14.60	285.55	23.8	144	24	992	195	15	33	94	8.97
14.1	0.0748	14.65	285.55	23.8	144	23	992	195	15	33	94	8.97
14.2	0.0748	14.65	285.55	23.8	144	23	992	195	14	33	93	8.97
14.4	0.0748	14.55	284.57	23.8	144	23	992	194	14	33	93	8.97
14.4	0.0748	14.60	285.94	23.8	144	23	992	194	14	33	93	8.97
14.4	-0.0044	14.55	285.55	23.8	144	23	992	194	14	33	93	8.97
14.4	-0.0044	14.55	285.35	23.8	144	23	992	194	14	33	93	8.97
14.4	-0.0044	14.60	285.35	23.8	144	23	965	194	14	33	93	8.97
14.4	-0.0044	14.65	285.55	23.8	144	23	99	194	14	33	93	8.97
14.4	-0.0044	14.65	285.16	23.8	144	23	26	194	14	33	93	8.97
13.5	-0.0044	14.65	285.35	16.3	6	21	26	214	14	35	214	0.13
13.6	-0.0044	14.65	285.35	16.3	6	21	26	214	14	35	214	0.13
13.5	-0.0044	14.60	285.35	16.3	6	21	26	214	14	36	214	0.13

13.6	-0.0044	14.65	285.55	16.3	6	21	26	213	14	37	214	0.13
13.6	-0.0044	14.60	285.35	16.3	6	21	26	213	14	37	214	0.13
13.6	-0.0044	14.60	286.52	16.3	6	21	26	213	14	37	214	0.13
13.6	-0.0044	14.60	284.38	16.3	6	21	26	213	14	37	214	0.13
13.4	-0.0044	14.65	285.35	16.3	6	19	26	213	14	41	213	0.13
13.2	-0.0044	14.60	284.96	16.3	6	19	26	214	14	42	214	0.13
13.4	-0.0044	14.65	285.35	16.3	6	19	26	214	14	44	214	0.13
13.4	-0.0044	14.60	284.38	16.3	6	19	26	214	14	44	214	0.13
13.4	-0.0044	14.60	285.16	16.3	6	19	26	214	14	44	214	0.13
13.1	-0.0044	14.60	285.74	16.3	6	18	26	213	14	45	214	0.13
13.1	-0.0044	14.60	285.35	16.3	6	18	26	213	14	44	214	0.13
13.1	-0.0044	14.65	285.35	16.3	6	18	26	213	14	44	214	0.13
13.1	-0.0044	14.65	285.74	16.3	6	18	26	213	14	44	214	0.13
13.2	-0.0044	14.60	285.94	16.4	6	18	26	213	13	44	213	0.13
13.2	-0.0044	14.60	285.16	16.4	6	18	26	213	13	44	213	0.13
13.2	-0.0044	14.60	285.16	16.4	6	18	26	213	13	44	213	0.13
13.3	-0.0044	14.65	285.35	16.3	6	17	26	213	13	45	213	0.13
13.3	-0.0044	14.60	286.33	16.3	6	17	26	213	13	45	213	0.13
13.3	-0.0044	14.60	285.35	16.3	6	17	992	213	13	45	213	0.13

13.5	-0.0044	14.60	285.35	24.2	144	18	992	146	13	48	36	8.97
13.7	-0.0044	14.60	285.55	24.4	144	19	992	176	13	46	38	8.97
13.7	0.0748	14.60	285.74	24.4	144	19	992	176	13	46	38	8.97
13.6	0.0748	14.60	285.16	24.1	140	19	84	205	13	37	203	0.13
13.4	0.0748	14.55	284.96	17.8	23	18	26	216	13	35	214	0.13
13.4	0.0748	14.65	285.35	17.8	23	18	314	216	13	35	214	0.13
13	0.0748	14.60	285.35	22.7	115	17	992	197	13	35	195	0.13
13	0.0748	14.60	285.35	22.7	115	17	992	197	13	35	195	0.13
14.1	0.0748	14.60	285.55	24.3	144	20	992	190	13	32	83	8.97
13.5	0.0748	14.65	285.74	24.4	144	19	992	190	13	32	83	8.97
13.5	0.0748	14.60	285.74	24.4	144	19	992	190	13	32	83	8.97
13.5	0.0748	14.60	284.77	24.4	144	19	992	190	13	32	83	8.97
13.5	0.0748	14.60	285.16	24.4	144	19	992	190	13	32	83	8.97
13.8	0.0748	14.65	285.74	24.3	144	20	992	192	13	29	59	8.98
13.8	0.0748	14.60	285.16	24.3	144	20	992	192	13	29	59	8.97
13.9	0.0748	14.65	285.35	24.2	144	20	992	194	13	29	74	8.97
13.7	0.0748	14.60	285.74	24.2	144	20	992	194	13	29	75	8.97
13.9	0.0748	14.60	284.77	24.2	144	20	992	193	13	29	76	8.97
13.9	0.0748	14.60	286.13	24.2	144	20	992	193	13	29	76	8.97

14	0.0748	14.60	284.77	24.1	144	21	992	195	13	31	76	8.97
14	0.0748	14.60	284.57	24.1	144	21	992	195	13	31	76	8.97
13.8	0.0748	14.65	284.77	24.1	144	21	992	193	13	32	77	8.97
13.8	0.0748	14.60	285.35	24.1	144	21	389	193	13	32	77	8.97
13.8	0.0748	14.65	285.35	24.1	144	21	37	193	13	32	77	8.97
13.8	0.0748	14.60	285.55	24.1	144	21	26	193	13	32	77	8.97

3.2 Final tuning of hydrogen car recorded data

Name:	Throttle Position	Engine speed	Lambda	Inj_End	IAdv	FAPW	AMass	MAP	AT	ET	NOx	CO2	CO	HC	O2
Unit:	%	RPM	La	^{o}CA	^{o}BTDC	ms	mg/ms	kPa	^{o}C	^{o}C	ppm	%	%	ppm	%
	26.39	1473	1.789	285	15.4	6.982	16.192	88.889	18.0	89.1	296	0.201	0.018	28	11.247
	26.38	1473	1.789	285	15.4	7.004	16.192	88.661	17.6	89.3	299	0.203	0.018	27	11.247
	26.40	1473	1.789	285	14.6	7.004	16.185	88.737	17.8	89.1	296	0.203	0.018	27	10.389
	26.39	1473	1.789	285	14.6	6.982	16.170	88.433	18.1	89.3	297	0.201	0.018	27	10.389
	26.38	1473	1.789	285	16.3	6.982	16.178	88.737	18.2	89.3	297	0.201	0.019	27	12.105
	26.37	1473	1.789	285	16.3	6.952	16.185	88.889	18.0	89.2	298	0.198	0.018	27	12.105
	26.36	1473	1.788	285	15.4	6.996	16.185	88.737	18.0	89.1	299	0.203	0.017	27	11.247
	26.37	1473	1.788	285	17.2	6.959	16.178	88.889	18.0	89.1	293	0.199	0.018	27	12.964
	26.35	1473	1.789	285	14.6	6.996	16.192	88.737	18.0	89.2	298	0.203	0.018	27	10.389
	26.38	1473	1.789	285	15.4	6.996	16.192	88.661	17.9	89.2	298	0.203	0.018	27	11.247
	26.35	1473	1.789	285	16.3	6.952	16.170	88.737	17.9	88.9	297	0.198	0.018	27	12.105
	26.33	1473	1.789	285	15.4	6.996	16.192	88.509	17.9	89.1	296	0.203	0.018	27	11.247
	26.35	1473	1.788	285	14.6	6.996	16.170	88.585	18.1	89.2	299	0.203	0.018	27	10.389
	26.36	1473	1.788	285	16.3	6.996	16.185	88.737	18.1	89.4	296	0.203	0.018	27	12.105
	26.35	1473	1.789	285	16.3	6.996	16.170	88.509	17.8	89.0	294	0.203	0.018	27	12.105
	26.36	1473	1.789	285	14.6	7.004	16.178	88.433	17.9	89.6	296	0.203	0.018	27	10.389

26.35	1473	1.789	285	14.6	6.989	16.230	88.585	18.2	89.2	296	0.202	0.017	27	10.389
26.35	1473	1.789	285	16.3	6.959	16.207	88.813	17.9	89.4	297	0.199	0.018	28	12.105
26.33	1473	1.789	285	13.7	6.982	16.237	88.737	18.0	89.2	298	0.201	0.018	27	9.531
26.34	1473	1.789	285	16.3	6.937	16.185	88.813	18.1	89.1	294	0.197	0.018	27	12.105
26.37	1473	1.788	285	15.4	7.011	16.163	88.509	18.1	89.2	296	0.204	0.018	27	11.247
26.34	1473	1.788	285	16.3	6.974	16.163	88.509	18.0	89.3	297	0.200	0.018	27	12.105
26.35	1473	1.789	285	16.3	6.982	16.185	88.585	17.9	89.1	296	0.201	0.018	27	12.105
26.34	1473	1.789	285	14.6	6.996	16.185	88.585	17.8	89.4	297	0.203	0.018	27	10.389
26.36	1473	1.788	285	15.4	7.004	16.207	89.117	18.0	88.8	298	0.203	0.017	27	11.247
26.29	1473	1.788	285	16.3	6.989	16.185	88.585	18.5	89.1	293	0.202	0.018	27	12.105
26.37	1473	1.788	285	15.4	7.004	16.163	88.661	17.7	89.1	297	0.203	0.018	27	11.247
26.34	1473	1.788	285	14.6	7.011	16.185	88.737	18.1	88.8	296	0.204	0.018	27	10.389
26.34	1473	1.788	285	15.4	6.974	16.215	88.889	17.9	89.1	303	0.200	0.017	27	11.247
26.35	1473	1.789	285	15.4	6.996	16.185	88.965	18.2	89.0	294	0.203	0.018	27	11.247
26.33	1473	1.788	285	16.3	6.974	16.207	89.041	18.0	88.9	298	0.200	0.018	27	12.105
26.34	1473	1.789	285	13.7	6.982	16.170	88.737	18.1	89.5	297	0.201	0.018	27	9.531
26.32	1473	1.788	285	14.6	6.996	16.170	88.509	18.5	89.3	296	0.203	0.018	27	10.389
26.32	1473	1.788	285	14.6	6.967	16.215	88.737	18.1	89.4	302	0.200	0.017	27	10.389
26.33	1473	1.788	285	15.4	6.996	16.222	88.889	18.4	89.0	297	0.203	0.017	27	11.247

26.29	1473	1.788	285	15.4	7.011	16.192	88.585	18.2	89.5	297	0.204	0.018	27	11.247
26.34	1473	1.788	285	13.7	6.982	16.185	88.661	17.9	89.5	296	0.201	0.018	27	9.531
26.33	1473	1.788	285	14.6	7.019	16.192	88.737	18.1	89.4	297	0.205	0.018	27	10.389
26.32	1473	1.789	285	14.6	7.011	16.192	89.117	18.1	89.3	291	0.204	0.018	27	10.389
26.37	1473	1.788	285	15.4	6.974	16.215	88.889	17.9	89.5	297	0.200	0.017	27	11.247
26.38	1473	1.788	285	15.4	6.982	16.200	89.117	17.8	89.1	291	0.201	0.018	27	11.247
26.37	1473	1.789	285	15.4	7.026	16.192	88.661	18.0	89.2	294	0.206	0.018	27	11.247
26.39	1473	1.789	285	15.4	7.004	16.222	89.041	18.4	89.4	293	0.203	0.018	27	11.247
26.39	1473	1.789	285	15.4	7.019	16.185	88.585	18.1	89.3	299	0.205	0.017	27	11.247
26.35	1473	1.789	285	14.6	6.982	16.207	88.965	17.8	89.2	294	0.201	0.017	26	10.389
26.38	1473	1.789	285	13.7	6.982	16.192	88.889	18.0	89.4	298	0.201	0.018	27	9.531
26.41	1473	1.789	285	16.3	7.004	16.192	88.661	18.0	89.2	296	0.203	0.018	27	12.105
26.27	1473	1.788	285	15.4	6.996	16.207	88.737	17.8	89.4	300	0.203	0.018	27	11.247
26.29	1473	1.788	285	16.3	6.959	16.163	88.433	17.7	89.5	294	0.199	0.018	27	12.105
26.31	1473	1.788	285	15.4	6.982	16.148	88.585	17.7	89.2	296	0.201	0.018	27	11.247
26.19	2024	1.703	315	10.0	7.362	17.472	76.161	24.3	85.4	175	0.206	0.010	30	10.672
26.19	2024	1.703	315	9.1	7.384	17.464	76.313	24.5	85.3	177	0.208	0.011	30	9.814
26.18	2024	1.703	315	10.9	7.376	17.472	76.313	24.4	85.1	182	0.208	0.011	30	11.531
26.18	2024	1.703	315	9.1	7.391	17.450	76.313	24.4	85.4	176	0.209	0.011	30	9.814

26.19	2024	1.703	315	10.0	7.354	17.427	76.161	24.7	85.2	177	0.205	0.011	30	10.672
26.19	2024	1.703	315	9.1	7.369	17.487	76.313	24.3	85.2	176	0.207	0.011	29	9.814
26.19	2024	1.703	315	10.0	7.376	17.472	76.237	24.4	84.8	178	0.208	0.012	30	10.672
26.21	2024	1.703	315	10.0	7.354	17.450	76.085	24.7	85.4	178	0.205	0.011	30	10.672
26.16	2024	1.704	315	10.0	7.332	17.427	75.933	24.1	84.9	176	0.203	0.011	30	10.672
26.19	2024	1.703	315	8.3	7.339	17.427	76.161	24.4	85.1	176	0.204	0.011	30	8.956
26.19	2024	1.703	315	10.0	7.362	17.427	75.781	24.6	85.3	179	0.206	0.010	30	10.672
26.18	2024	1.703	315	10.0	7.362	17.450	76.313	24.5	85.1	178	0.206	0.011	30	10.672
26.19	2024	1.703	315	10.0	7.362	17.464	76.389	24.2	84.9	184	0.206	0.011	30	10.672
26.16	2024	1.703	315	10.0	7.369	17.450	76.237	24.3	85.1	181	0.207	0.011	30	10.672
26.19	2024	1.703	315	8.3	7.339	17.450	76.313	24.8	84.8	172	0.204	0.011	30	8.956
26.19	2024	1.703	315	8.3	7.384	17.427	76.237	24.4	85.1	177	0.208	0.011	30	8.956
26.16	2024	1.703	315	9.1	7.347	17.435	76.161	24.2	85.0	177	0.205	0.011	30	9.814
26.16	2024	1.703	315	10.0	7.369	17.450	76.161	24.2	85.0	177	0.207	0.010	30	10.672
26.16	2024	1.703	315	10.0	7.354	17.442	76.237	24.4	85.0	182	0.205	0.011	30	10.672
26.19	2024	1.703	315	9.1	7.362	17.464	76.009	24.3	85.5	175	0.206	0.011	30	9.814
26.16	2024	1.703	315	10.0	7.369	17.442	76.161	24.4	85.0	177	0.207	0.011	30	10.672
26.16	2024	1.703	315	9.1	7.362	17.420	76.085	24.4	85.2	171	0.206	0.011	30	9.814
26.16	2024	1.703	315	10.0	7.362	17.427	76.009	24.6	84.9	177	0.206	0.011	30	10.672

26.16	2024	1.703	315	9.1	7.384	17.450	76.237	24.6	85.4	177	0.208	0.010	30	9.814
26.16	2024	1.703	315	8.3	7.391	17.442	76.085	24.4	85.4	175	0.209	0.010	30	8.956
26.19	2024	1.703	315	9.1	7.354	17.472	76.161	24.7	85.1	170	0.205	0.011	30	9.814
26.16	2024	1.703	315	9.1	7.339	17.435	76.237	24.5	85.0	178	0.204	0.010	30	9.814
26.16	2024	1.703	315	10.0	7.391	17.457	76.237	24.4	85.3	178	0.209	0.010	30	10.672
26.16	2024	1.703	315	9.1	7.376	17.457	76.313	24.5	85.3	179	0.208	0.010	29	9.814
26.14	2024	1.703	315	10.0	7.347	17.472	76.389	24.7	85.4	179	0.205	0.011	30	10.672
26.14	2024	1.703	315	8.3	7.376	17.450	76.465	24.4	85.3	177	0.208	0.011	30	8.956
26.16	2024	1.703	315	9.1	7.391	17.479	76.161	24.3	85.1	178	0.209	0.011	29	9.814
26.14	2024	1.703	315	10.0	7.369	17.464	76.389	24.4	85.3	173	0.207	0.011	30	10.672
26.16	2024	1.703	315	8.3	7.376	17.450	76.389	24.2	85.4	177	0.208	0.011	30	8.956
26.19	2024	1.703	315	10.0	7.376	17.472	76.161	24.7	85.4	178	0.208	0.011	30	10.672
26.16	2024	1.703	315	8.3	7.362	17.457	76.465	24.4	85.4	173	0.206	0.012	30	8.956
26.14	2024	1.703	315	8.3	7.376	17.472	76.161	24.4	85.1	181	0.208	0.011	30	8.956
26.19	2024	1.703	315	10.0	7.376	17.464	76.313	24.4	85.3	175	0.208	0.011	29	10.672
26.16	2024	1.703	315	9.1	7.354	17.457	76.313	24.6	85.2	176	0.205	0.011	30	9.814
26.16	2024	1.703	315	10.0	7.362	17.472	76.161	24.4	85.1	176	0.206	0.011	30	10.672
26.19	2024	1.703	315	8.3	7.369	17.494	76.389	24.5	85.4	178	0.207	0.012	30	8.956
26.18	2024	1.703	315	8.3	7.369	17.464	76.389	24.4	85.2	176	0.207	0.011	30	8.956

26.19	2024	1.703	315	8.3	7.376	17.457	75.933	24.4	85.2	178	0.208	0.011	30	8.956
26.11	2024	1.703	315	9.1	7.384	17.435	76.389	24.5	85.3	176	0.208	0.011	30	9.814
26.16	2024	1.703	315	9.1	7.347	17.457	76.085	24.4	85.3	171	0.205	0.010	29	9.814
26.16	2024	1.703	315	10.0	7.391	17.487	76.389	24.3	84.9	173	0.209	0.011	30	10.672
26.16	2024	1.703	315	9.1	7.391	17.457	76.313	24.4	85.1	176	0.209	0.011	30	9.814
26.06	2024	1.702	315	10.0	7.362	17.450	76.009	24.3	85.1	182	0.206	0.011	30	10.672
26.04	2024	1.702	315	8.3	7.362	17.442	76.237	24.2	85.1	179	0.206	0.010	30	8.956
26.06	2024	1.702	315	9.1	7.354	17.450	76.237	24.5	85.3	178	0.205	0.011	30	9.814
25.75	3073	1.666	360	12.0	7.383	18.182	57.237	18.3	89.0	515	0.241	0.021	39	11.715
25.78	3073	1.666	360	11.2	7.368	18.175	57.389	17.8	89.2	517	0.240	0.020	39	10.857
25.80	3073	1.666	360	12.0	7.406	18.182	57.161	17.8	88.9	522	0.243	0.022	39	11.715
25.77	3073	1.666	360	12.0	7.368	18.182	57.389	18.2	89.0	520	0.240	0.021	39	11.715
25.79	3073	1.666	360	12.9	7.376	18.145	57.313	18.1	89.2	517	0.240	0.022	39	12.573
25.79	3073	1.666	360	12.0	7.398	18.160	57.541	18.3	88.7	519	0.242	0.021	39	11.715
25.78	3073	1.666	360	12.0	7.383	18.182	57.313	18.4	88.9	517	0.241	0.022	39	11.715
25.83	3073	1.666	360	12.0	7.391	18.168	57.389	18.0	89.0	515	0.242	0.022	38	11.715
25.82	3073	1.666	360	12.9	7.383	18.182	57.237	18.0	88.9	517	0.241	0.022	39	12.573
25.79	3073	1.666	360	12.0	7.391	18.160	57.465	18.0	89.1	520	0.242	0.023	39	11.715
25.75	3073	1.666	360	12.0	7.361	18.197	57.313	18.3	89.0	517	0.239	0.021	39	11.715

25.79	3073	1.666	360	12.0	7.376	18.153	57.237	18.0	88.9	520	0.240	0.022	39	11.715
25.79	3073	1.666	360	12.0	7.376	18.190	57.313	18.1	89.0	522	0.240	0.023	39	11.715
25.82	3073	1.666	360	12.9	7.383	18.168	57.313	18.0	89.3	520	0.241	0.020	39	12.573
25.81	3073	1.666	360	11.2	7.361	18.168	57.541	17.8	89.2	517	0.239	0.020	39	10.857
25.80	3073	1.666	360	12.0	7.398	18.160	57.009	17.9	88.9	519	0.242	0.021	39	11.715
25.77	3073	1.666	360	12.0	7.376	18.168	57.085	17.9	89.0	521	0.240	0.021	39	11.715
25.80	3073	1.666	360	12.0	7.361	18.190	57.009	17.9	88.8	522	0.239	0.021	40	11.715
25.82	3073	1.666	360	12.9	7.383	18.160	57.085	18.0	89.0	523	0.241	0.021	39	12.573
25.79	3073	1.666	360	12.9	7.383	18.138	56.933	17.9	88.9	520	0.241	0.020	39	12.573
25.80	3073	1.666	360	12.0	7.376	18.160	57.085	17.8	89.0	521	0.240	0.021	39	11.715
25.79	3073	1.666	360	12.9	7.361	18.153	57.085	17.8	89.0	521	0.239	0.021	39	12.573
25.77	3073	1.666	360	12.0	7.368	18.153	57.009	17.9	88.9	520	0.240	0.022	39	11.715
25.79	3073	1.666	360	12.9	7.361	18.153	57.085	18.1	88.9	526	0.239	0.021	39	12.573
25.79	3073	1.666	360	12.9	7.354	18.168	57.085	17.8	88.6	523	0.238	0.021	39	12.573
25.80	3073	1.666	360	12.9	7.391	18.160	56.933	17.8	88.8	521	0.242	0.021	39	12.573
25.80	3073	1.666	360	13.8	7.376	18.138	57.161	17.8	88.7	516	0.240	0.022	40	13.432
25.75	3073	1.666	360	11.2	7.361	18.153	56.857	18.1	89.0	523	0.239	0.022	39	10.857
25.79	3073	1.666	360	11.2	7.339	18.153	56.781	18.1	89.1	521	0.237	0.020	39	10.857
25.75	3073	1.666	360	12.0	7.376	18.138	57.161	17.9	88.6	520	0.240	0.021	39	11.715

25.79	3073	1.666	360	12.0	7.354	18.145	57.161	18.1	88.8	519	0.238	0.022	39	11.715
25.78	3073	1.666	360	11.2	7.361	18.160	57.237	17.9	88.7	516	0.239	0.021	39	10.857
25.76	3073	1.666	360	12.0	7.368	18.130	57.009	17.9	88.7	517	0.240	0.022	39	11.715
25.78	3073	1.666	360	12.9	7.368	18.130	56.933	17.8	88.6	522	0.240	0.021	39	12.573
25.79	3073	1.666	360	12.9	7.391	18.160	57.465	18.0	88.6	525	0.242	0.022	39	12.573
25.78	3073	1.666	360	12.9	7.354	18.175	57.237	17.9	88.9	516	0.238	0.022	39	12.573
25.79	3073	1.666	360	12.0	7.354	18.190	57.009	18.1	88.7	522	0.238	0.022	39	11.715
25.79	3073	1.666	360	12.0	7.376	18.168	57.313	17.9	88.8	516	0.240	0.021	39	11.715
25.77	3073	1.666	360	12.9	7.368	18.182	57.161	17.9	89.0	520	0.240	0.021	39	12.573
25.73	3073	1.666	360	12.0	7.383	18.160	57.085	17.8	88.7	517	0.241	0.021	39	11.715
25.77	3073	1.666	360	12.0	7.391	18.175	57.313	18.2	89.0	522	0.242	0.021	38	11.715
25.77	3073	1.666	360	12.0	7.391	18.168	57.389	18.0	89.1	517	0.242	0.020	39	11.715
25.77	3073	1.666	360	11.2	7.376	18.160	57.009	18.5	89.2	517	0.240	0.020	39	10.857
25.77	3073	1.666	360	10.3	7.406	18.182	57.389	17.8	89.0	520	0.243	0.022	38	9.999
25.77	3073	1.666	360	12.9	7.383	18.168	57.313	18.3	88.9	520	0.241	0.022	39	12.573
25.78	3073	1.666	360	11.2	7.391	18.168	57.313	18.2	89.0	519	0.242	0.022	39	10.857
25.79	3073	1.666	360	12.0	7.376	18.153	57.161	18.2	88.9	520	0.240	0.020	39	11.715
25.69	3073	1.665	360	12.9	7.376	18.145	57.237	17.7	88.9	519	0.240	0.021	39	12.573
25.69	3073	1.665	360	12.0	7.346	18.153	57.161	17.8	88.9	522	0.237	0.021	39	11.715

25.71	3073	1.665	360	12.0	7.376	18.160	57.389	17.8	89.1	520	0.240	0.022	39	11.715
50.30	1465	1.682	300	17.0	8.154	16.281	98.811	17.6	86.5	355	0.230	0.012	22	35.596
50.29	1465	1.682	300	17.0	8.176	16.289	98.735	17.7	86.5	358	0.232	0.013	23	35.596
50.33	1465	1.682	300	16.1	8.206	16.296	98.507	17.5	86.5	355	0.235	0.012	23	34.738
50.29	1465	1.681	300	17.9	8.214	16.281	98.583	17.8	86.7	357	0.236	0.012	22	36.454
50.32	1465	1.682	300	17.9	8.191	16.311	98.735	17.8	86.4	354	0.234	0.012	23	36.454
50.33	1465	1.682	300	17.0	8.184	16.304	98.887	17.6	86.2	351	0.233	0.014	23	35.596
50.33	1465	1.682	300	17.9	8.236	16.296	98.659	17.8	86.4	357	0.238	0.012	23	36.454
50.29	1465	1.682	300	17.9	8.191	16.289	98.659	17.8	86.6	353	0.234	0.014	22	36.454
50.33	1465	1.682	300	17.0	8.191	16.296	98.431	17.7	86.5	360	0.234	0.012	23	35.596
50.33	1465	1.681	300	17.9	8.176	16.274	98.583	17.9	86.3	355	0.232	0.012	23	36.454
50.33	1465	1.682	300	17.9	8.199	16.289	98.659	17.9	86.5	355	0.235	0.012	22	36.454
50.33	1465	1.682	300	17.0	8.191	16.289	98.963	17.7	86.5	358	0.234	0.013	23	35.596
50.33	1465	1.682	300	17.0	8.206	16.281	98.355	17.8	86.4	351	0.235	0.012	23	35.596
50.28	1465	1.682	300	17.9	8.191	16.259	98.811	17.6	86.3	353	0.234	0.013	23	36.454
50.33	1465	1.682	300	17.9	8.176	16.304	98.659	17.8	86.3	357	0.232	0.013	23	36.454
50.31	1465	1.682	300	16.1	8.169	16.259	98.735	17.8	86.3	351	0.232	0.012	23	34.738
50.33	1465	1.682	300	17.0	8.191	16.289	98.887	17.7	86.6	360	0.234	0.012	22	35.596
50.30	1465	1.682	300	17.9	8.169	16.266	98.963	17.6	86.5	354	0.232	0.012	23	36.454

50.32	1465	1.682	300	17.9	8.176	16.289	98.583	17.5	86.4	354	0.232	0.012	22	36.454
50.28	1465	1.681	300	17.0	8.191	16.266	98.659	17.3	86.3	351	0.234	0.012	23	35.596
50.29	1465	1.681	300	17.0	8.206	16.281	98.431	17.5	86.5	358	0.235	0.012	23	35.596
50.28	1465	1.681	300	17.9	8.206	16.266	98.507	17.6	86.8	357	0.235	0.013	22	36.454
50.29	1465	1.681	300	17.0	8.169	16.274	98.659	17.6	86.6	357	0.232	0.012	23	35.596
50.29	1465	1.681	300	17.9	8.191	16.252	98.507	17.8	86.3	357	0.234	0.012	22	36.454
50.28	1465	1.681	300	17.0	8.161	16.289	98.507	17.8	86.3	355	0.231	0.012	23	35.596
50.28	1465	1.681	300	16.1	8.184	16.281	98.507	17.6	86.5	355	0.233	0.013	23	34.738
50.28	1465	1.681	300	17.0	8.199	16.274	98.507	17.6	86.2	354	0.235	0.012	22	35.596
50.25	1465	1.681	300	17.0	8.191	16.289	98.583	17.6	86.3	358	0.234	0.013	23	35.596
50.22	1465	1.681	300	17.9	8.154	16.274	98.507	17.8	86.4	358	0.230	0.012	23	36.454
50.29	1465	1.681	300	17.9	8.199	16.274	98.735	17.7	86.4	355	0.235	0.012	23	36.454
50.26	1465	1.681	300	16.1	8.176	16.281	98.279	17.6	86.3	357	0.232	0.013	23	34.738
50.25	1465	1.682	300	17.0	8.176	16.259	98.507	17.5	86.2	352	0.232	0.012	22	35.596
50.29	1465	1.681	300	17.0	8.206	16.266	98.659	17.5	86.3	353	0.235	0.013	23	35.596
50.25	1465	1.681	300	16.1	8.169	16.318	98.507	17.4	86.3	358	0.232	0.013	22	34.738
50.25	1465	1.681	300	17.9	8.184	16.289	98.431	17.9	86.2	355	0.233	0.012	23	36.454
50.26	1465	1.681	300	17.0	8.176	16.266	98.507	17.8	86.3	354	0.232	0.012	23	35.596
50.28	1465	1.681	300	17.9	8.184	16.296	98.507	17.7	86.5	351	0.233	0.014	22	36.454

50.28	1465	1.681	300	17.0	8.184	16.289	98.735	17.8	86.5	352	0.233	0.012	23	35.596
50.26	1465	1.681	300	17.0	8.184	16.274	98.583	17.8	86.5	354	0.233	0.012	23	35.596
50.29	1465	1.681	300	17.9	8.154	16.304	98.735	17.6	86.3	353	0.230	0.013	22	36.454
50.28	1465	1.681	300	16.1	8.184	16.281	98.583	17.7	86.3	355	0.233	0.013	23	34.738
50.28	1465	1.681	300	17.0	8.184	16.281	98.583	17.8	86.3	354	0.233	0.012	22	35.596
50.28	1465	1.681	300	17.0	8.176	16.296	98.735	17.7	86.4	357	0.232	0.013	23	35.596
50.29	1465	1.681	300	17.0	8.206	16.259	98.507	17.6	86.4	358	0.235	0.012	23	35.596
50.28	1465	1.681	300	17.0	8.184	16.304	98.583	17.8	86.6	358	0.233	0.013	22	35.596
50.28	1465	1.681	300	17.0	8.184	16.289	98.431	17.8	86.3	355	0.233	0.014	23	35.596
50.22	1465	1.681	300	17.0	8.169	16.266	98.735	17.5	86.4	360	0.232	0.012	22	35.596
50.18	1465	1.681	300	17.0	8.199	16.266	98.887	17.6	86.4	355	0.235	0.012	23	35.596
50.24	1465	1.681	300	17.0	8.169	16.274	98.583	17.6	86.3	355	0.232	0.012	23	35.596
50.28	1465	1.681	300	17.0	8.184	16.289	98.735	17.8	86.5	352	0.233	0.012	23	35.596
50.24	2029	1.616	325	10.0	8.367	19.623	96.930	14.5	86.6	191	0.203	0.027	45	11.002
50.24	2029	1.616	325	10.0	8.322	19.601	96.701	14.7	86.7	189	0.199	0.027	46	11.002
50.25	2029	1.616	325	10.9	8.360	19.601	96.777	14.8	86.7	185	0.202	0.027	45	11.860
50.27	2029	1.616	325	8.3	8.367	19.616	97.082	14.7	86.3	185	0.203	0.027	45	9.286
50.26	2029	1.616	325	9.1	8.345	19.601	96.549	14.7	86.6	185	0.201	0.028	46	10.144
50.32	2029	1.616	325	10.9	8.330	19.616	96.397	14.5	86.7	189	0.199	0.027	45	11.860

50.28	2029	1.616	325	9.1	8.367	19.586	96.701	14.8	86.7	185	0.203	0.027	46	10.144
50.30	2029	1.616	325	10.0	8.330	19.623	96.625	14.7	86.6	191	0.199	0.027	46	11.002
50.30	2029	1.616	325	10.0	8.360	19.586	96.930	14.1	86.6	189	0.202	0.027	45	11.002
50.30	2029	1.616	325	10.0	8.352	19.586	96.625	14.7	86.6	188	0.202	0.027	45	11.002
50.32	2029	1.616	325	10.0	8.337	19.601	96.854	14.6	86.9	186	0.200	0.027	45	11.002
50.30	2029	1.617	325	10.0	8.345	19.593	96.473	14.5	86.5	184	0.201	0.027	45	11.002
50.29	2029	1.617	325	10.9	8.352	19.593	96.625	14.3	86.6	188	0.202	0.026	45	11.860
50.28	2029	1.616	325	9.1	8.352	19.616	96.321	14.4	86.5	186	0.202	0.027	45	10.144
50.28	2029	1.616	325	10.0	8.345	19.586	96.625	14.1	86.9	184	0.201	0.027	45	11.002
50.30	2029	1.617	325	10.0	8.337	19.616	96.701	14.2	86.9	191	0.200	0.027	46	11.002
50.29	2029	1.616	325	9.1	8.307	19.601	96.625	14.4	86.5	186	0.197	0.026	45	10.144
50.28	2029	1.616	325	9.1	8.330	19.608	96.321	14.2	86.6	186	0.199	0.027	45	10.144
50.26	2029	1.617	325	10.9	8.337	19.608	96.473	14.5	86.6	188	0.200	0.027	45	11.860
50.30	2029	1.616	325	9.1	8.330	19.586	96.549	14.4	86.7	190	0.199	0.027	45	10.144
50.28	2029	1.616	325	10.9	8.300	19.579	96.701	14.4	86.8	184	0.196	0.027	45	11.860
50.30	2029	1.616	325	10.9	8.337	19.593	96.854	14.7	86.7	183	0.200	0.027	45	11.860
50.30	2029	1.616	325	9.1	8.352	19.608	96.777	14.1	86.6	189	0.202	0.027	46	10.144
50.27	2029	1.616	325	9.1	8.330	19.608	96.549	14.6	86.6	191	0.199	0.028	45	10.144
50.28	2029	1.616	325	10.0	8.337	19.593	96.549	14.6	86.6	189	0.200	0.027	45	11.002

50.28	2029	1.616	325	10.0	8.367	19.608	96.777	14.6	86.6	188	0.203	0.027	45	11.002
50.29	2029	1.616	325	8.3	8.352	19.601	96.701	14.4	86.5	186	0.202	0.028	45	9.286
50.28	2029	1.616	325	10.0	8.330	19.601	96.701	14.7	86.7	185	0.199	0.027	45	11.002
50.27	2029	1.616	325	10.0	8.345	19.608	96.549	14.5	86.7	188	0.201	0.027	45	11.002
50.26	2029	1.616	325	9.1	8.375	19.593	96.930	14.8	86.7	191	0.204	0.027	46	10.144
50.24	2029	1.616	325	9.1	8.367	19.586	96.777	14.4	87.0	186	0.203	0.027	45	10.144
50.24	2029	1.616	325	9.1	8.360	19.601	96.777	14.8	86.9	186	0.202	0.027	46	10.144
50.23	2029	1.616	325	9.1	8.352	19.593	96.777	14.5	86.6	185	0.202	0.028	46	10.144
50.26	2029	1.616	325	10.0	8.330	19.556	96.701	14.7	86.5	189	0.199	0.027	45	11.002
50.27	2029	1.616	325	8.3	8.345	19.608	96.854	14.7	86.7	189	0.201	0.027	45	9.286
50.26	2029	1.616	325	9.1	8.330	19.616	96.625	14.4	86.6	185	0.199	0.027	45	10.144
50.25	2029	1.616	325	10.0	8.337	19.586	96.854	14.5	86.9	184	0.200	0.028	45	11.002
50.29	2029	1.616	325	9.1	8.367	19.593	96.701	14.3	86.8	189	0.203	0.028	45	10.144
50.23	2029	1.616	325	9.1	8.345	19.601	96.777	14.2	86.7	186	0.201	0.027	45	10.144
50.26	2029	1.616	325	10.0	8.330	19.601	96.397	14.7	86.6	189	0.199	0.028	45	11.002
50.26	2029	1.616	325	9.1	8.330	19.586	96.701	14.4	86.6	188	0.199	0.028	45	10.144
50.29	2029	1.616	325	9.1	8.337	19.579	96.701	14.2	86.6	191	0.200	0.027	46	10.144
50.25	2029	1.616	325	8.3	8.337	19.616	96.549	14.5	86.8	190	0.200	0.027	45	9.286
50.25	2029	1.616	325	10.9	8.345	19.586	96.625	14.4	86.9	191	0.201	0.027	46	11.860

50.27	2029	1.616	325	9.1	8.330	19.608	96.625	14.3	86.4	186	0.199	0.027	45	10.144
50.30	2029	1.616	325	9.1	8.307	19.593	96.473	14.3	86.8	189	0.197	0.028	45	10.144
50.23	2029	1.616	325	10.0	8.322	19.571	96.473	14.2	86.6	188	0.199	0.028	46	11.002
50.22	2029	1.616	325	10.0	8.330	19.579	96.169	14.4	86.4	197	0.199	0.028	46	11.002
50.23	2029	1.616	325	10.0	8.307	19.564	96.701	13.9	86.6	194	0.197	0.027	46	11.002
50.26	2029	1.616	325	10.0	8.330	19.556	96.701	14.7	86.5	189	0.199	0.027	45	11.002
50.11	3031	1.689	380	15.0	8.550	23.490	94.938	16.9	87.7	341	0.120	0.018	34	11.101
50.15	3031	1.689	380	15.0	8.587	23.490	95.242	17.2	87.7	335	0.124	0.017	35	11.101
50.11	3031	1.689	380	15.9	8.542	23.505	95.242	17.1	87.5	336	0.119	0.018	34	11.959
50.12	3031	1.689	380	15.9	8.564	23.490	94.938	17.3	87.7	339	0.121	0.019	33	11.959
50.13	3031	1.689	380	15.0	8.550	23.490	94.862	17.2	88.0	339	0.120	0.017	34	11.101
50.12	3031	1.689	380	14.1	8.602	23.505	94.862	17.1	87.7	337	0.125	0.019	34	10.243
50.10	3031	1.689	380	15.0	8.564	23.520	95.166	16.9	87.7	337	0.121	0.018	34	11.101
50.16	3031	1.689	380	15.9	8.594	23.520	94.862	17.2	88.0	336	0.124	0.018	33	11.959
50.11	3031	1.689	380	15.0	8.564	23.512	95.014	17.2	87.6	335	0.121	0.019	34	11.101
50.11	3031	1.689	380	15.0	8.579	23.512	95.014	16.9	87.7	336	0.123	0.018	34	11.101
50.16	3031	1.689	380	14.1	8.579	23.497	94.786	16.9	87.6	335	0.123	0.019	34	10.243
50.14	3031	1.689	380	15.9	8.564	23.497	94.786	16.9	87.7	335	0.121	0.017	34	11.959
50.10	3031	1.689	380	15.0	8.579	23.505	95.090	17.2	87.5	337	0.123	0.018	34	11.101

50.10	3031	1.689	380	15.0	8.550	23.497	94.786	17.0	87.9	339	0.120	0.019	34	11.101
50.12	3031	1.689	380	15.0	8.550	23.512	94.634	16.9	87.7	343	0.120	0.017	34	11.101
50.12	3031	1.689	380	15.0	8.542	23.490	94.786	17.1	87.7	336	0.119	0.018	34	11.101
50.08	3031	1.689	380	15.0	8.564	23.490	94.938	16.9	87.7	346	0.121	0.018	34	11.101
50.10	3031	1.689	380	15.0	8.542	23.482	95.014	17.1	87.5	339	0.119	0.019	34	11.101
50.08	3031	1.688	380	15.9	8.572	23.497	95.090	16.9	87.6	339	0.122	0.017	34	11.959
50.08	3031	1.689	380	15.9	8.557	23.490	94.862	17.3	87.4	335	0.121	0.017	34	11.959
50.06	3031	1.688	380	14.1	8.512	23.468	94.938	17.1	87.7	341	0.116	0.017	34	10.243
50.07	3031	1.688	380	15.9	8.535	23.475	94.710	17.1	87.6	334	0.119	0.018	34	11.959
50.04	3031	1.689	380	15.9	8.550	23.497	95.090	17.1	87.4	337	0.120	0.017	34	11.959
50.07	3031	1.689	380	14.1	8.527	23.475	94.938	17.3	87.7	336	0.118	0.017	34	10.243
50.07	3031	1.689	380	15.9	8.557	23.505	94.786	16.9	87.4	335	0.121	0.018	34	11.959
50.08	3031	1.689	380	15.0	8.527	23.475	94.938	16.9	87.7	335	0.118	0.019	34	11.101
50.08	3031	1.689	380	15.9	8.572	23.460	94.938	16.8	87.3	335	0.122	0.017	34	11.959
50.09	3031	1.689	380	15.0	8.557	23.475	94.710	16.9	87.5	336	0.121	0.018	34	11.101
50.09	3031	1.689	380	15.0	8.564	23.490	95.166	16.9	87.8	337	0.121	0.018	34	11.101
50.12	3031	1.689	380	13.3	8.550	23.482	94.634	17.0	87.4	331	0.120	0.019	34	9.385
50.04	3031	1.688	380	15.0	8.564	23.468	94.634	17.1	87.7	335	0.121	0.017	34	11.101
50.05	3031	1.689	380	14.1	8.564	23.527	95.014	16.8	87.7	336	0.121	0.017	34	10.243

50.08	3031	1.689	380	14.1	8.542	23.505	94.786	16.9	87.6	341	0.119	0.020	34	10.243
50.04	3031	1.689	380	15.9	8.564	23.505	95.166	17.1	87.4	339	0.121	0.019	34	11.959
50.07	3031	1.689	380	15.0	8.594	23.512	94.558	17.1	87.7	336	0.124	0.016	34	11.101
50.08	3031	1.689	380	15.0	8.542	23.512	94.938	17.3	87.7	336	0.119	0.017	34	11.101
50.07	3031	1.689	380	15.0	8.550	23.490	95.166	16.9	87.5	335	0.120	0.017	34	11.101
50.10	3031	1.689	380	13.3	8.557	23.497	94.938	17.1	87.6	335	0.121	0.018	34	9.385
50.11	3031	1.689	380	14.1	8.572	23.490	94.938	17.2	87.4	334	0.122	0.017	34	10.243
50.11	3031	1.689	380	14.1	8.557	23.527	94.862	16.8	87.7	335	0.121	0.018	33	10.243
50.11	3031	1.689	380	15.9	8.564	23.468	95.014	16.7	87.4	336	0.121	0.019	34	11.959
50.11	3031	1.689	380	14.1	8.564	23.505	95.166	17.1	87.8	333	0.121	0.018	33	10.243
50.12	3031	1.689	380	14.1	8.550	23.490	95.014	17.1	87.6	335	0.120	0.018	34	10.243
50.08	3031	1.689	380	15.0	8.550	23.512	95.090	17.1	87.4	340	0.120	0.018	34	11.101
50.08	3031	1.689	380	15.0	8.572	23.468	94.710	16.9	87.5	336	0.122	0.017	34	11.101
50.10	3031	1.689	380	15.0	8.564	23.505	95.014	16.9	87.4	336	0.121	0.017	34	11.101
50.08	3031	1.689	380	15.0	8.557	23.490	95.014	17.1	87.4	334	0.121	0.017	34	11.101
50.07	3031	1.689	380	15.0	8.527	23.482	95.014	16.8	87.6	340	0.118	0.018	34	11.101
50.12	3031	1.689	380	13.3	8.550	23.482	94.634	17.0	87.4	331	0.120	0.019	34	9.385
50.04	3031	1.688	380	15.0	8.564	23.468	94.634	17.1	87.7	335	0.121	0.017	34	11.101
50.44	4045	1.977	407	17.0	7.701	28.420	89.296	20.3	89.7	100	0.159	0.019	32	11.298

50.47	4045	1.977	407	17.9	7.708	28.397	88.992	20.3	89.6	104	0.160	0.018	33	12.156
50.47	4045	1.977	407	16.1	7.730	28.405	89.372	20.0	89.7	98	0.162	0.019	33	10.440
50.48	4045	1.977	407	16.1	7.701	28.405	89.296	20.1	89.5	97	0.159	0.018	32	10.440
50.45	4045	1.977	407	17.0	7.730	28.397	88.992	20.4	89.7	98	0.162	0.021	32	11.298
50.45	4045	1.977	407	17.0	7.715	28.427	89.296	20.1	89.5	103	0.160	0.018	32	11.298
50.45	4045	1.977	407	17.0	7.708	28.397	89.372	20.0	89.7	109	0.160	0.018	32	11.298
50.44	4045	1.977	407	17.9	7.730	28.405	89.448	20.3	89.4	103	0.162	0.018	32	12.156
50.48	4045	1.977	407	18.7	7.730	28.427	89.068	20.3	89.7	101	0.162	0.018	33	13.014
50.48	4045	1.977	407	17.0	7.708	28.397	89.144	20.1	89.2	98	0.160	0.019	32	11.298
50.48	4045	1.977	407	17.9	7.708	28.405	89.296	20.2	89.6	101	0.160	0.019	32	12.156
50.44	4045	1.977	407	17.0	7.730	28.405	89.448	20.1	89.4	101	0.162	0.019	32	11.298
50.45	4045	1.977	407	17.9	7.730	28.435	89.296	20.3	89.7	99	0.162	0.019	32	12.156
50.45	4045	1.977	407	17.0	7.701	28.427	88.916	20.4	89.7	103	0.159	0.019	32	11.298
50.40	4045	1.976	407	17.0	7.708	28.420	89.524	20.3	89.5	99	0.160	0.019	32	11.298
50.45	4045	1.977	407	17.0	7.760	28.420	89.524	20.2	89.4	100	0.165	0.018	33	11.298
50.45	4045	1.976	407	16.1	7.745	28.420	89.220	20.3	89.6	100	0.163	0.019	32	10.440
50.41	4045	1.976	407	16.1	7.753	28.427	89.144	20.3	89.6	99	0.164	0.019	32	10.440
50.45	4045	1.976	407	17.9	7.730	28.435	89.372	20.4	89.7	101	0.162	0.019	32	12.156
50.42	4045	1.976	407	17.0	7.708	28.405	89.144	20.4	90.0	99	0.160	0.018	32	11.298

50.44	4045	1.977	407	16.1	7.723	28.412	89.068	20.2	89.6	101	0.161	0.020	32	10.440
50.41	4045	1.977	407	17.0	7.708	28.412	88.992	20.1	89.7	101	0.160	0.020	32	11.298
50.45	4045	1.977	407	15.3	7.730	28.412	89.372	20.0	89.7	99	0.162	0.018	32	9.581
50.44	4045	1.977	407	17.0	7.738	28.412	89.144	20.0	89.4	95	0.163	0.019	32	11.298
50.46	4045	1.977	407	17.0	7.715	28.420	89.220	20.0	89.5	101	0.160	0.018	32	11.298
50.45	4045	1.977	407	17.0	7.708	28.397	88.992	20.6	89.5	99	0.160	0.018	32	11.298
50.45	4045	1.977	407	17.0	7.715	28.420	89.220	20.0	89.4	94	0.160	0.020	32	11.298
50.44	4045	1.977	407	17.0	7.730	28.397	89.068	20.3	89.4	101	0.162	0.020	32	11.298
50.48	4045	1.977	407	17.9	7.701	28.405	88.992	20.0	89.6	101	0.159	0.019	32	12.156
50.44	4045	1.977	407	16.1	7.701	28.397	89.144	19.9	89.7	105	0.159	0.019	32	10.440
50.47	4045	1.977	407	17.9	7.730	28.412	89.144	20.0	89.4	98	0.162	0.019	32	12.156
50.44	4045	1.977	407	17.9	7.730	28.420	89.068	20.2	89.2	103	0.162	0.019	32	12.156
50.44	4045	1.977	407	17.0	7.686	28.382	88.992	20.1	89.9	101	0.158	0.019	32	11.298
50.44	4045	1.977	407	17.0	7.686	28.420	89.220	20.2	89.4	95	0.158	0.020	32	11.298
50.46	4045	1.976	407	16.1	7.708	28.420	89.144	20.2	89.3	100	0.160	0.018	33	10.440
50.45	4045	1.977	407	17.0	7.715	28.397	89.296	20.2	89.6	101	0.160	0.019	32	11.298
50.42	4045	1.977	407	17.9	7.730	28.390	89.372	20.3	89.4	101	0.162	0.020	33	12.156
50.45	4045	1.977	407	17.0	7.693	28.397	88.992	20.0	89.3	100	0.158	0.019	32	11.298
50.46	4045	1.976	407	16.1	7.671	28.405	89.144	20.4	89.8	94	0.156	0.021	32	10.440

50.39	4045	1.976	407	17.0	7.715	28.420	89.220	19.9	89.5	100	0.160	0.020	32	11.298
50.42	4045	1.977	407	17.0	7.715	28.382	89.144	20.2	89.9	100	0.160	0.018	32	11.298
50.43	4045	1.976	407	16.1	7.715	28.382	89.220	20.1	89.4	98	0.160	0.020	32	10.440
50.41	4045	1.976	407	17.0	7.730	28.412	88.916	20.2	89.7	98	0.162	0.019	32	11.298
50.43	4045	1.976	407	17.0	7.723	28.427	89.068	20.0	89.6	103	0.161	0.019	33	11.298
50.41	4045	1.976	407	17.9	7.753	28.412	88.916	20.1	89.9	95	0.164	0.019	32	12.156
50.42	4045	1.977	407	17.0	7.738	28.420	89.220	20.2	89.7	95	0.163	0.018	32	11.298
50.43	4045	1.977	407	17.9	7.738	28.435	89.144	20.4	89.7	101	0.163	0.017	32	12.156
50.42	4045	1.977	407	17.0	7.693	28.412	89.144	20.0	89.4	107	0.158	0.021	33	11.298
50.42	4045	1.977	407	17.0	7.708	28.412	89.220	20.1	89.6	100	0.160	0.018	32	11.298
50.48	4045	1.977	407	17.9	7.701	28.405	88.992	20.0	89.6	101	0.159	0.019	32	12.156
74.84	1489	1.484	285	10.0	8.763	17.021	100.022	16.7	85.3	1302	0.081	0.025	31	9.669
74.83	1489	1.484	285	8.3	8.741	17.028	99.870	16.9	85.3	1304	0.079	0.023	31	7.953
74.84	1489	1.484	285	9.1	8.733	16.984	99.794	16.5	84.9	1306	0.078	0.024	31	8.811
74.82	1489	1.484	285	9.1	8.778	17.006	100.174	16.3	85.1	1306	0.082	0.024	31	8.811
74.84	1489	1.484	285	8.3	8.756	17.013	99.946	16.5	85.3	1305	0.080	0.024	31	7.953
74.81	1489	1.484	285	7.4	8.748	17.028	100.022	16.7	85.3	1308	0.080	0.025	30	7.095
74.82	1489	1.484	285	8.3	8.748	16.999	99.946	16.7	85.0	1309	0.080	0.024	31	7.953
74.84	1489	1.484	285	8.3	8.741	17.013	99.794	16.2	85.3	1304	0.079	0.024	30	7.953

74.85	1489	1.484	285	10.0	8.763	16.999	99.946	16.5	85.0	1310	0.081	0.024	30	9.669
74.82	1489	1.484	285	8.3	8.748	17.013	99.794	16.6	84.8	1308	0.080	0.024	30	7.953
74.83	1489	1.484	285	10.0	8.748	16.984	99.794	16.9	85.0	1308	0.080	0.023	31	9.669
74.84	1489	1.484	285	10.0	8.771	16.991	100.022	16.5	85.5	1308	0.082	0.024	31	9.669
74.84	1489	1.484	285	9.1	8.733	16.999	99.870	16.3	85.0	1308	0.078	0.023	31	8.811
74.82	1489	1.484	285	9.1	8.741	17.006	99.642	16.4	85.3	1310	0.079	0.024	31	8.811
74.83	1489	1.484	285	10.0	8.748	16.991	99.870	16.7	85.2	1308	0.080	0.023	30	9.669
74.82	1489	1.483	285	9.1	8.771	17.028	99.794	16.9	85.3	1305	0.082	0.022	31	8.811
74.83	1489	1.484	285	9.1	8.763	17.036	99.946	16.7	85.3	1304	0.081	0.024	31	8.811
74.81	1489	1.484	285	8.3	8.763	16.991	100.022	16.9	85.3	1303	0.081	0.025	30	7.953
74.82	1489	1.484	285	8.3	8.756	17.021	100.174	16.9	85.1	1298	0.080	0.023	30	7.953
74.80	1489	1.484	285	9.1	8.756	17.006	99.566	16.6	85.3	1309	0.080	0.023	31	8.811
74.83	1489	1.484	285	7.4	8.756	17.021	99.718	16.8	85.0	1306	0.080	0.025	31	7.095
74.81	1489	1.484	285	8.3	8.756	17.021	100.098	16.7	85.3	1309	0.080	0.025	31	7.953
74.78	1489	1.484	285	10.0	8.771	17.028	100.022	16.7	85.3	1306	0.082	0.023	30	9.669
74.80	1489	1.484	285	7.4	8.763	17.028	100.098	16.7	85.3	1306	0.081	0.024	30	7.095
74.81	1489	1.484	285	8.3	8.763	17.051	100.098	17.0	85.3	1304	0.081	0.023	30	7.953
74.82	1489	1.484	285	8.3	8.756	17.013	100.250	16.9	85.6	1308	0.080	0.024	31	7.953
74.80	1489	1.484	285	7.4	8.778	17.036	100.098	17.0	85.2	1304	0.082	0.023	31	7.095

74.79	1489	1.484	285	8.3	8.786	17.021	99.870	16.7	85.3	1304	0.083	0.023	31	7.953
74.77	1489	1.484	285	9.1	8.771	17.043	100.326	16.9	85.3	1304	0.082	0.023	31	8.811
74.80	1489	1.484	285	8.3	8.801	16.999	100.098	16.9	85.3	1306	0.085	0.023	30	7.953
74.80	1489	1.484	285	9.1	8.771	17.006	99.870	17.0	85.1	1306	0.082	0.024	31	8.811
74.82	1489	1.484	285	8.3	8.786	17.006	100.022	17.0	85.5	1306	0.083	0.024	31	7.953
74.78	1489	1.483	285	8.3	8.778	17.043	100.098	16.7	85.2	1308	0.082	0.023	30	7.953
74.78	1489	1.484	285	9.1	8.748	17.028	100.250	16.7	85.1	1309	0.080	0.024	31	8.811
74.82	1489	1.484	285	9.1	8.763	17.028	99.794	16.5	85.3	1310	0.081	0.023	31	8.811
74.77	1489	1.484	285	8.3	8.786	17.028	100.098	16.5	85.2	1306	0.083	0.024	31	7.953
74.79	1489	1.483	285	10.0	8.756	17.006	100.022	16.9	85.3	1308	0.080	0.024	31	9.669
74.80	1489	1.483	285	8.3	8.771	17.013	99.794	16.7	85.3	1305	0.082	0.023	31	7.953
74.78	1489	1.483	285	9.1	8.726	17.013	100.022	16.4	85.5	1305	0.077	0.025	31	8.811
74.79	1489	1.484	285	8.3	8.771	16.976	99.794	16.5	85.0	1309	0.082	0.024	31	7.953
74.81	1489	1.484	285	10.0	8.786	17.006	99.642	16.9	85.0	1304	0.083	0.024	31	9.669
74.81	1489	1.484	285	8.3	8.771	17.006	99.946	16.5	85.3	1310	0.082	0.025	31	7.953
74.78	1489	1.484	285	10.0	8.748	17.013	99.566	16.4	85.1	1310	0.080	0.024	31	9.669
74.80	1489	1.484	285	10.0	8.763	16.999	99.794	16.7	85.2	1308	0.081	0.023	31	9.669
74.79	1489	1.484	285	10.0	8.733	16.999	99.870	16.6	85.2	1311	0.078	0.024	31	9.669
74.83	1489	1.484	285	10.0	8.726	17.036	99.794	17.0	85.3	1310	0.077	0.023	31	9.669

74.84	1489	1.484	285	9.1	8.711	16.969	99.946	16.4	84.8	1309	0.076	0.024	31	8.811
74.79	1489	1.484	285	9.1	8.763	16.969	99.946	16.6	85.1	1306	0.081	0.023	31	8.811
74.80	1489	1.484	285	8.3	8.733	17.006	99.718	16.6	85.0	1310	0.078	0.023	31	7.953
74.78	1489	1.483	285	9.1	8.726	17.013	100.022	16.4	85.5	1305	0.077	0.025	31	8.811
74.84	2029	1.523	310	12.0	8.869	20.021	99.919	16.5	87.8	892	0.068	0.022	31	10.327
74.86	2029	1.522	310	12.0	8.899	20.058	99.767	16.1	88.1	893	0.071	0.021	30	10.327
74.82	2029	1.522	310	12.9	8.884	20.028	99.767	16.7	88.0	892	0.069	0.020	30	11.186
74.85	2029	1.523	310	12.0	8.876	20.051	100.071	16.0	88.0	887	0.069	0.021	30	10.327
74.82	2029	1.522	310	12.9	8.876	20.036	100.071	16.5	88.0	889	0.069	0.020	31	11.186
74.80	2029	1.523	310	12.9	8.884	20.065	99.767	16.3	88.3	893	0.069	0.020	30	11.186
74.85	2029	1.523	310	12.0	8.899	20.043	99.919	16.4	87.8	895	0.071	0.020	30	10.327
74.84	2029	1.523	310	12.9	8.876	20.051	99.995	16.2	88.0	894	0.069	0.021	30	11.186
74.82	2029	1.523	310	12.0	8.884	20.065	99.843	16.5	88.1	893	0.069	0.020	31	10.327
74.83	2029	1.523	310	12.9	8.906	20.051	99.919	16.2	87.9	893	0.072	0.021	30	11.186
74.82	2029	1.523	310	12.0	8.899	20.036	99.843	16.5	88.1	893	0.071	0.019	31	10.327
74.80	2029	1.523	310	13.7	8.847	20.043	99.767	16.2	88.0	893	0.066	0.021	31	12.044
74.82	2029	1.523	310	12.9	8.891	20.073	99.995	16.1	88.1	898	0.070	0.021	31	11.186
74.83	2029	1.523	310	12.0	8.884	20.065	99.843	16.7	88.1	888	0.069	0.020	31	10.327
74.80	2029	1.523	310	13.7	8.899	20.036	100.071	16.5	88.1	895	0.071	0.021	31	12.044

74.80	2029	1.523	310	12.0	8.884	20.036	99.919	16.5	87.9	890	0.069	0.022	31	10.327
74.85	2029	1.523	310	13.7	8.861	20.051	99.843	16.4	87.7	890	0.067	0.020	31	12.044
74.82	2029	1.523	310	12.9	8.891	20.051	99.919	16.2	87.9	892	0.070	0.021	31	11.186
74.88	2029	1.523	310	12.0	8.854	20.051	99.691	16.3	88.0	895	0.067	0.020	31	10.327
74.84	2029	1.523	310	11.1	8.884	20.013	99.539	16.2	88.0	894	0.069	0.020	31	9.469
74.82	2029	1.523	310	12.9	8.854	20.021	99.767	16.3	87.8	892	0.067	0.021	31	11.186
74.84	2029	1.523	310	13.7	8.869	20.028	99.615	16.1	87.8	896	0.068	0.021	31	12.044
74.82	2029	1.523	310	12.0	8.891	20.013	99.843	16.3	87.7	889	0.070	0.020	31	10.327
74.84	2029	1.523	310	12.9	8.847	20.021	99.387	16.2	87.9	894	0.066	0.020	31	11.186
74.83	2029	1.523	310	13.7	8.884	20.043	99.539	16.2	88.0	892	0.069	0.020	31	12.044
74.84	2029	1.523	310	12.9	8.876	20.036	99.995	15.9	87.7	892	0.069	0.020	31	11.186
74.85	2029	1.523	310	12.0	8.876	20.021	99.463	16.2	87.7	889	0.069	0.021	31	10.327
74.84	2029	1.523	310	12.9	8.876	19.999	99.995	16.0	88.1	895	0.069	0.021	31	11.186
74.82	2029	1.523	310	12.0	8.847	20.021	99.539	16.5	88.0	893	0.066	0.022	31	10.327
74.83	2029	1.523	310	14.6	8.839	19.991	99.463	16.4	87.9	890	0.065	0.020	31	12.902
74.83	2029	1.523	310	12.9	8.847	20.013	99.615	16.0	87.7	893	0.066	0.022	31	11.186
74.85	2029	1.523	310	12.9	8.876	20.051	99.615	16.3	87.7	892	0.069	0.020	31	11.186
74.84	2029	1.523	310	12.0	8.854	20.028	99.767	16.4	87.9	890	0.067	0.022	30	10.327
74.82	2029	1.523	310	12.0	8.869	20.036	99.615	16.2	88.0	893	0.068	0.022	31	10.327

74.83	2029	1.522	310	12.0	8.861	20.006	99.767	16.2	88.0	890	0.067	0.019	30	10.327
74.80	2029	1.522	310	12.0	8.899	20.013	99.919	16.5	88.0	894	0.071	0.020	31	10.327
74.80	2029	1.522	310	12.9	8.861	20.036	99.767	16.2	88.0	893	0.067	0.022	30	11.186
74.82	2029	1.522	310	12.0	8.899	20.028	99.767	16.6	88.1	887	0.071	0.021	31	10.327
74.80	2029	1.523	310	12.9	8.906	20.058	100.071	16.3	87.9	889	0.072	0.020	30	11.186
74.80	2029	1.523	310	12.9	8.876	20.036	99.615	16.2	88.0	890	0.069	0.020	31	11.186
74.82	2029	1.523	310	11.1	8.891	20.043	99.767	16.4	88.1	886	0.070	0.021	31	9.469
74.80	2029	1.522	310	11.1	8.891	20.036	99.919	16.3	88.0	894	0.070	0.021	31	9.469
74.80	2029	1.522	310	12.9	8.847	20.051	99.767	16.2	87.8	890	0.066	0.022	31	11.186
74.80	2029	1.522	310	12.0	8.876	20.036	99.919	16.5	88.0	890	0.069	0.021	31	10.327
74.79	2029	1.523	310	12.0	8.876	20.065	99.919	16.6	88.1	894	0.069	0.021	31	10.327
74.78	2029	1.522	310	12.9	8.906	20.043	99.767	16.8	88.1	887	0.072	0.020	31	11.186
74.79	2029	1.523	310	13.7	8.876	20.021	99.767	15.9	87.7	893	0.069	0.021	31	12.044
74.83	2029	1.523	310	12.9	8.854	20.028	99.843	15.9	87.7	894	0.067	0.021	31	11.186
74.82	2029	1.523	310	12.9	8.854	20.021	99.463	16.0	87.7	892	0.067	0.021	31	11.186
74.80	2029	1.522	310	12.9	8.847	20.051	99.767	16.2	87.8	890	0.066	0.022	31	11.186
74.74	3055	1.482	380	12.0	9.601	25.424	99.330	17.2	89.4	2225	0.088	0.022	36	9.363
74.74	3055	1.482	380	12.9	9.586	25.432	99.177	17.3	89.4	2225	0.087	0.021	36	10.221
74.74	3055	1.482	380	11.1	9.616	25.424	98.949	17.4	89.2	2223	0.089	0.022	37	8.504

74.73	3055	1.482	380	12.9	9.623	25.432	99.254	17.3	89.3	2231	0.090	0.022	37	10.221
74.76	3055	1.482	380	10.3	9.586	25.417	98.949	17.2	89.2	2227	0.087	0.022	36	7.646
74.74	3055	1.482	380	10.3	9.571	25.417	99.101	17.4	89.3	2223	0.085	0.021	36	7.646
74.74	3055	1.482	380	12.0	9.616	25.409	98.949	17.0	89.2	2225	0.089	0.022	36	9.363
74.76	3055	1.482	380	12.0	9.586	25.417	98.797	17.3	89.2	2234	0.087	0.022	37	9.363
74.72	3055	1.482	380	12.0	9.601	25.447	99.101	17.2	89.2	2225	0.088	0.022	36	9.363
74.79	3055	1.482	380	12.9	9.578	25.432	99.101	17.2	89.2	2227	0.086	0.022	37	10.221
74.76	3055	1.482	380	10.3	9.586	25.409	99.177	17.1	89.0	2225	0.087	0.022	37	7.646
74.74	3055	1.482	380	11.1	9.556	25.395	98.721	17.2	89.1	2228	0.084	0.022	37	8.504
74.74	3055	1.482	380	12.9	9.563	25.439	99.254	17.0	89.2	2227	0.084	0.022	37	10.221
74.73	3055	1.482	380	10.3	9.586	25.409	99.101	17.5	89.4	2225	0.087	0.022	37	7.646
74.76	3055	1.482	380	12.0	9.556	25.417	99.177	17.1	89.2	2226	0.084	0.022	37	9.363
74.74	3055	1.482	380	11.1	9.586	25.402	98.949	17.2	89.0	2231	0.087	0.022	37	8.504
74.72	3055	1.482	380	12.9	9.578	25.417	98.873	17.3	89.2	2228	0.086	0.022	36	10.221
74.72	3055	1.482	380	12.0	9.601	25.417	98.949	17.2	89.2	2227	0.088	0.021	37	9.363
74.74	3055	1.482	380	11.1	9.578	25.395	98.873	17.3	89.1	2225	0.086	0.021	36	8.504
74.73	3055	1.482	380	12.0	9.563	25.432	98.645	17.2	89.0	2226	0.084	0.021	36	9.363
74.74	3055	1.482	380	11.1	9.541	25.417	98.873	17.5	88.9	2227	0.082	0.022	36	8.504
74.76	3055	1.482	380	12.9	9.571	25.424	98.873	16.9	89.2	2228	0.085	0.022	37	10.221

74.73	3055	1.482	380	12.9	9.601	25.402	98.797	17.1	89.2	2228	0.088	0.022	37	10.221
74.72	3055	1.483	380	12.0	9.563	25.372	98.873	17.2	89.3	2228	0.084	0.022	36	9.363
74.69	3055	1.482	380	10.3	9.571	25.417	99.025	17.0	89.2	2226	0.085	0.022	37	7.646
74.72	3055	1.482	380	12.9	9.548	25.439	98.873	17.2	89.3	2229	0.083	0.021	37	10.221
74.71	3055	1.482	380	12.0	9.578	25.417	98.873	17.3	89.3	2226	0.086	0.022	36	9.363
74.71	3055	1.482	380	11.1	9.586	25.395	98.797	17.2	89.2	2229	0.087	0.022	37	8.504
74.69	3055	1.482	380	11.1	9.593	25.387	98.797	17.3	89.1	2227	0.087	0.022	37	8.504
74.72	3055	1.482	380	12.0	9.571	25.417	98.721	17.1	89.1	2226	0.085	0.021	36	9.363
74.71	3055	1.482	380	10.3	9.578	25.409	99.254	17.2	89.3	2227	0.086	0.022	37	7.646
74.72	3055	1.482	380	12.0	9.563	25.424	98.873	17.1	89.0	2229	0.084	0.022	37	9.363
74.72	3055	1.482	380	12.9	9.578	25.439	98.645	17.5	89.2	2226	0.086	0.022	37	10.221
74.74	3055	1.482	380	12.0	9.578	25.417	98.949	17.1	89.2	2231	0.086	0.021	37	9.363
74.74	3055	1.482	380	12.0	9.571	25.409	98.873	17.2	88.9	2223	0.085	0.023	37	9.363
74.76	3055	1.482	380	12.0	9.563	25.424	98.721	17.4	89.2	2231	0.084	0.022	37	9.363
74.76	3055	1.482	380	11.1	9.593	25.432	99.177	17.0	89.2	2231	0.087	0.022	37	8.504
74.74	3055	1.483	380	12.0	9.593	25.424	99.025	17.2	89.2	2226	0.087	0.022	37	9.363
74.77	3055	1.483	380	12.0	9.563	25.402	98.949	17.2	89.0	2225	0.084	0.023	37	9.363
74.79	3056	1.483	380	12.9	9.578	25.432	98.873	17.2	89.4	2227	0.086	0.022	37	10.221
74.74	3055	1.483	380	12.9	9.571	25.402	98.949	17.2	89.2	2226	0.085	0.022	37	10.221

74.78	3055	1.483	380	12.0	9.556	25.439	99.101	17.2	89.2	2229	0.084	0.022	37	9.363
74.79	3055	1.483	380	11.1	9.601	25.402	99.482	17.5	89.4	2223	0.088	0.020	36	8.504
74.81	3055	1.483	380	11.1	9.563	25.417	99.177	17.2	89.4	2226	0.084	0.022	37	8.504
74.82	3055	1.482	380	12.0	9.571	25.432	99.101	17.3	89.4	2231	0.085	0.022	37	9.363
74.78	3056	1.483	380	12.0	9.586	25.417	98.873	17.4	89.2	2228	0.087	0.022	37	9.363
74.81	3055	1.483	380	12.0	9.563	25.424	99.025	17.0	89.2	2228	0.084	0.021	37	9.363
74.78	3056	1.483	380	12.0	9.563	25.402	98.949	16.9	89.0	2235	0.084	0.022	37	9.363
74.81	3055	1.483	380	12.9	9.548	25.380	99.101	17.0	88.9	2228	0.083	0.021	37	10.221
74.76	3055	1.482	380	12.0	9.563	25.424	98.721	17.4	89.2	2231	0.084	0.022	37	9.363
74.24	4039	1.558	460	12.0	10.576	29.724	98.430	21.2	90.2	934	0.116	0.020	34	12.438
74.24	4039	1.558	460	12.0	10.561	29.702	98.354	21.5	90.3	943	0.115	0.020	35	12.438
74.25	4039	1.559	460	10.3	10.568	29.732	98.201	21.6	90.4	940	0.115	0.020	34	10.721
74.24	4039	1.558	460	11.1	10.553	29.717	98.201	21.5	90.4	939	0.114	0.022	34	11.579
74.25	4039	1.558	460	11.1	10.576	29.732	98.354	21.3	90.2	938	0.116	0.021	34	11.579
74.26	4039	1.558	460	12.0	10.561	29.717	98.125	21.2	90.5	937	0.115	0.020	35	12.438
74.27	4039	1.558	460	12.9	10.561	29.724	98.201	21.3	90.5	943	0.115	0.022	34	13.296
74.26	4039	1.558	460	12.0	10.561	29.724	98.430	21.2	90.6	945	0.115	0.021	34	12.438
74.21	4039	1.559	460	12.9	10.553	29.747	98.201	21.2	90.2	942	0.114	0.021	34	13.296
74.24	4039	1.558	460	12.9	10.538	29.702	98.049	21.3	90.2	944	0.112	0.022	35	13.296

74.22	4039	1.558	460	12.0	10.538	29.724	98.354	21.1	90.1	940	0.112	0.023	35	12.438
74.27	4039	1.558	460	12.0	10.598	29.762	98.277	21.4	90.2	940	0.118	0.021	34	12.438
74.26	4039	1.558	460	12.9	10.538	29.717	98.277	21.2	90.3	940	0.112	0.021	35	13.296
74.25	4039	1.558	460	12.9	10.538	29.732	97.973	21.1	90.3	940	0.112	0.021	35	13.296
74.27	4039	1.559	460	11.1	10.538	29.724	98.201	21.2	90.3	944	0.112	0.022	34	11.579
74.27	4039	1.558	460	12.0	10.546	29.695	98.125	21.2	90.4	944	0.113	0.021	35	12.438
74.23	4039	1.559	460	12.9	10.553	29.687	98.201	21.1	90.0	940	0.114	0.021	34	13.296
74.22	4039	1.558	460	12.0	10.493	29.695	98.125	21.2	90.1	942	0.108	0.020	35	12.438
74.26	4039	1.558	460	12.0	10.523	29.680	97.973	21.4	90.4	939	0.111	0.020	35	12.438
74.27	4039	1.558	460	12.9	10.538	29.672	98.049	20.9	89.9	940	0.112	0.021	34	13.296
74.28	4039	1.559	460	12.9	10.538	29.724	98.049	21.2	90.4	943	0.112	0.022	35	13.296
74.27	4039	1.558	460	12.0	10.516	29.695	98.049	21.2	90.1	946	0.110	0.021	35	12.438
74.27	4040	1.559	460	12.0	10.523	29.709	98.201	21.2	90.2	945	0.111	0.021	35	12.438
74.28	4040	1.559	460	12.9	10.531	29.709	98.201	21.0	90.0	946	0.112	0.021	34	13.296
74.30	4039	1.559	460	12.9	10.538	29.709	98.125	21.2	89.7	942	0.112	0.020	34	13.296
74.27	4039	1.559	460	12.9	10.538	29.695	98.277	21.2	90.2	938	0.112	0.021	34	13.296
74.30	4039	1.559	460	12.9	10.538	29.695	98.354	21.1	90.2	943	0.112	0.021	35	13.296
74.27	4039	1.558	460	13.7	10.553	29.709	98.049	21.3	90.2	940	0.114	0.021	34	14.154
74.26	4039	1.558	460	12.0	10.531	29.717	98.354	21.2	90.2	943	0.112	0.020	34	12.438

74.27	4039	1.558	460	12.0	10.561	29.717	98.582	21.1	90.5	942	0.115	0.022	35	12.438
74.28	4040	1.559	460	12.0	10.546	29.739	98.354	21.4	90.3	939	0.113	0.021	34	12.438
74.26	4039	1.558	460	12.0	10.576	29.724	98.430	21.6	90.5	939	0.116	0.021	34	12.438
74.26	4039	1.558	460	12.9	10.561	29.739	98.430	21.5	90.4	943	0.115	0.022	34	13.296
74.24	4039	1.559	460	12.9	10.546	29.747	98.201	21.5	90.2	940	0.113	0.021	35	13.296
74.25	4039	1.558	460	11.1	10.546	29.739	98.201	21.7	90.4	942	0.113	0.021	34	11.579
74.25	4039	1.558	460	12.0	10.583	29.754	98.354	21.4	90.4	943	0.117	0.022	34	12.438
74.21	4039	1.558	460	11.1	10.561	29.717	98.277	21.5	90.6	942	0.115	0.021	34	11.579
74.23	4039	1.559	460	12.0	10.583	29.754	98.430	21.3	90.5	942	0.117	0.021	34	12.438
74.22	4039	1.559	460	11.1	10.561	29.739	98.430	21.5	90.6	942	0.115	0.021	35	11.579
74.20	4039	1.558	460	12.0	10.598	29.754	98.430	21.5	90.6	940	0.118	0.021	34	12.438
74.22	4039	1.558	460	12.0	10.553	29.724	98.277	21.5	90.5	938	0.114	0.021	35	12.438
74.15	4039	1.558	460	12.9	10.561	29.739	98.582	21.8	90.7	943	0.115	0.020	35	13.296
74.22	4039	1.558	460	12.0	10.568	29.732	98.506	21.5	90.2	937	0.115	0.022	34	12.438
74.22	4039	1.558	460	10.3	10.583	29.754	98.430	21.7	90.2	940	0.117	0.021	34	10.721
74.21	4039	1.558	460	12.0	10.576	29.754	98.125	21.4	90.9	942	0.116	0.021	34	12.438
74.20	4039	1.558	460	11.1	10.591	29.724	98.277	21.2	90.2	942	0.117	0.021	34	11.579
74.23	4039	1.559	460	12.0	10.576	29.724	98.354	21.3	90.3	942	0.116	0.021	34	12.438
74.27	4039	1.559	460	12.0	10.538	29.724	98.201	21.0	90.4	939	0.112	0.022	34	12.438

74.30	4039	1.559	460	12.0	10.546	29.709	98.049	21.3	90.0	943	0.113	0.023	34	12.438
74.20	4039	1.558	460	12.0	10.598	29.754	98.430	21.5	90.6	940	0.118	0.021	34	12.438
99.34	1441	1.417	310	15.0	9.789	16.524	100.630	9.0	84.8	1362	0.116	0.020	33	12.414
99.33	1441	1.417	310	14.1	9.744	16.480	100.401	9.2	84.7	1357	0.112	0.020	33	11.556
99.34	1441	1.417	310	14.1	9.759	16.517	100.021	9.0	84.8	1360	0.113	0.020	33	11.556
99.32	1441	1.418	310	13.3	9.759	16.495	100.173	8.8	84.7	1360	0.113	0.021	33	10.698
99.34	1441	1.417	310	14.1	9.811	16.517	100.401	9.0	84.4	1362	0.118	0.020	33	11.556
99.37	1441	1.418	310	14.1	9.751	16.495	100.325	8.6	84.9	1361	0.112	0.019	33	11.556
99.33	1441	1.417	310	15.0	9.744	16.480	100.097	9.0	84.3	1362	0.112	0.022	33	12.414
99.32	1441	1.417	310	14.1	9.759	16.472	100.173	8.9	84.6	1361	0.113	0.021	33	11.556
99.33	1441	1.417	310	12.4	9.751	16.502	100.021	8.9	84.5	1358	0.112	0.021	33	9.840
99.29	1441	1.417	310	14.1	9.766	16.495	100.173	8.6	84.3	1357	0.114	0.020	33	11.556
99.29	1441	1.417	310	14.1	9.744	16.495	100.173	8.6	84.5	1362	0.112	0.021	33	11.556
99.26	1441	1.417	310	14.1	9.766	16.495	100.097	8.9	84.4	1358	0.114	0.021	34	11.556
99.28	1441	1.417	310	13.3	9.736	16.457	100.325	8.6	84.7	1358	0.111	0.020	34	10.698
99.29	1441	1.417	310	14.1	9.759	16.472	100.325	8.7	84.5	1361	0.113	0.020	34	11.556
99.28	1441	1.417	310	13.3	9.759	16.465	99.945	8.6	84.3	1362	0.113	0.020	33	10.698
99.29	1441	1.417	310	13.3	9.774	16.495	100.477	8.6	84.7	1358	0.115	0.019	33	10.698
99.31	1441	1.417	310	15.0	9.774	16.472	100.477	8.7	84.5	1356	0.115	0.019	33	12.414

99.28	1441	1.417	310	14.1	9.766	16.502	100.097	8.9	84.6	1362	0.114	0.021	33	11.556
99.29	1441	1.417	310	13.3	9.759	16.487	100.325	9.0	84.3	1355	0.113	0.021	33	10.698
99.31	1441	1.417	310	15.9	9.774	16.509	100.097	8.8	84.9	1361	0.115	0.020	34	13.272
99.31	1441	1.417	310	13.3	9.774	16.487	100.097	9.0	84.6	1357	0.115	0.022	33	10.698
99.33	1441	1.417	310	14.1	9.789	16.487	100.325	9.0	84.6	1355	0.116	0.019	33	11.556
99.29	1441	1.417	310	14.1	9.766	16.509	100.325	9.2	84.6	1360	0.114	0.020	33	11.556
99.32	1441	1.417	310	13.3	9.781	16.532	100.325	8.9	84.6	1363	0.115	0.021	33	10.698
99.32	1441	1.417	310	12.4	9.774	16.487	100.477	8.9	84.6	1356	0.115	0.020	33	9.840
99.31	1441	1.417	310	15.9	9.796	16.495	100.325	9.3	84.9	1358	0.117	0.020	32	13.272
99.28	1441	1.417	310	15.0	9.781	16.539	100.706	9.2	84.6	1358	0.115	0.019	33	12.414
99.33	1441	1.417	310	15.0	9.781	16.547	100.706	9.2	84.8	1358	0.115	0.020	33	12.414
99.31	1441	1.417	310	14.1	9.804	16.517	100.630	9.0	84.9	1357	0.117	0.019	33	11.556
99.29	1441	1.417	310	14.1	9.796	16.524	100.630	9.4	84.6	1356	0.117	0.019	33	11.556
99.29	1441	1.417	310	13.3	9.796	16.539	100.401	9.1	85.2	1360	0.117	0.020	33	10.698
99.33	1441	1.417	310	13.3	9.781	16.524	100.477	9.1	84.9	1355	0.115	0.019	33	10.698
99.34	1441	1.417	310	14.1	9.796	16.517	100.706	9.2	85.0	1360	0.117	0.021	33	11.556
99.31	1441	1.417	310	15.0	9.789	16.524	100.554	8.9	85.0	1357	0.116	0.021	33	12.414
99.34	1441	1.417	310	14.1	9.796	16.517	100.325	9.2	84.6	1357	0.117	0.020	33	11.556
99.34	1441	1.417	310	13.3	9.796	16.502	100.173	9.2	84.7	1356	0.117	0.019	33	10.698

99.36	1441	1.418	310	13.3	9.751	16.509	100.401	9.1	84.9	1361	0.112	0.019	33	10.698
99.36	1442	1.417	310	13.3	9.781	16.495	100.401	9.0	84.3	1360	0.115	0.020	33	10.698
99.36	1442	1.418	310	14.1	9.774	16.509	100.554	8.9	84.7	1361	0.115	0.019	33	11.556
99.34	1441	1.418	310	15.0	9.781	16.495	100.173	8.9	84.6	1358	0.115	0.021	33	12.414
99.36	1441	1.418	310	13.3	9.819	16.509	100.173	8.9	84.5	1363	0.119	0.021	33	10.698
99.34	1441	1.418	310	14.1	9.751	16.532	100.325	9.0	84.9	1360	0.112	0.019	33	11.556
99.34	1441	1.417	310	14.1	9.781	16.480	100.401	9.0	84.6	1361	0.115	0.020	33	11.556
99.34	1441	1.417	310	13.3	9.759	16.472	100.173	8.9	84.7	1360	0.113	0.020	33	10.698
99.34	1441	1.417	310	15.0	9.781	16.480	100.477	9.0	84.8	1355	0.115	0.019	33	12.414
99.33	1441	1.418	310	14.1	9.774	16.509	100.173	8.9	84.5	1358	0.115	0.020	33	11.556
99.42	1441	1.418	310	13.3	9.744	16.524	100.249	8.9	84.6	1363	0.112	0.019	33	10.698
99.38	1441	1.418	310	14.1	9.736	16.517	100.249	8.9	84.4	1354	0.111	0.020	33	11.556
99.41	1442	1.418	310	13.3	9.789	16.495	100.325	8.9	84.7	1356	0.116	0.021	33	10.698
99.33	1441	1.418	310	14.1	9.774	16.509	100.173	8.9	84.5	1358	0.115	0.020	33	11.556
99.05	1951	1.507	340	12.0	9.379	19.926	100.040	8.7	85.6	379	0.125	0.020	34	12.395
98.99	1951	1.506	340	12.0	9.365	19.992	99.888	8.5	85.6	379	0.124	0.021	34	12.395
99.02	1951	1.507	340	11.1	9.357	19.948	99.736	8.5	85.7	383	0.123	0.021	34	11.536
99.02	1951	1.507	340	10.3	9.372	19.948	100.268	8.5	85.6	377	0.124	0.021	34	10.678
99.05	1951	1.506	340	12.0	9.379	19.933	100.040	9.0	85.7	380	0.125	0.020	34	12.395

99.02	1952	1.507	340	13.7	9.357	19.970	100.344	8.6	85.7	383	0.123	0.021	34	14.111
99.02	1951	1.506	340	11.1	9.379	19.978	100.192	8.4	85.6	383	0.125	0.021	34	11.536
98.99	1951	1.506	340	11.1	9.365	19.970	100.192	8.9	85.8	378	0.124	0.021	34	11.536
99.03	1951	1.506	340	12.9	9.394	19.978	100.420	8.6	85.8	382	0.126	0.021	34	13.253
99.02	1951	1.507	340	12.0	9.394	19.978	100.268	8.7	85.9	385	0.126	0.021	34	12.395
99.03	1951	1.507	340	11.1	9.379	19.970	100.344	8.7	85.8	380	0.125	0.021	35	11.536
99.07	1951	1.507	340	13.7	9.394	19.963	100.192	8.8	85.8	382	0.126	0.022	34	14.111
99.07	1951	1.507	340	11.1	9.379	19.955	100.192	8.7	85.8	380	0.125	0.022	34	11.536
99.05	1951	1.507	340	12.9	9.357	19.970	100.344	8.6	85.6	379	0.123	0.021	34	13.253
99.05	1952	1.507	340	11.1	9.394	19.963	100.268	8.7	85.7	379	0.126	0.021	34	11.536
99.07	1952	1.507	340	11.1	9.379	19.940	100.344	8.7	85.8	384	0.125	0.021	34	11.536
99.07	1952	1.507	340	12.0	9.387	19.970	100.496	8.7	85.9	382	0.126	0.021	34	12.395
99.10	1952	1.507	340	11.1	9.387	19.955	100.040	9.0	85.7	380	0.126	0.021	34	11.536
99.07	1952	1.507	340	12.9	9.372	19.985	100.268	8.6	85.9	382	0.124	0.021	34	13.253
99.10	1952	1.507	340	11.1	9.372	19.992	100.344	8.9	86.3	379	0.124	0.021	34	11.536
99.08	1952	1.507	340	12.0	9.379	19.985	100.344	8.7	85.6	380	0.125	0.020	34	12.395
99.08	1952	1.507	340	11.1	9.365	19.955	100.040	8.7	85.9	380	0.124	0.021	34	11.536
99.10	1952	1.507	340	12.9	9.402	19.970	100.268	8.7	85.9	382	0.127	0.021	34	13.253
99.10	1952	1.507	340	11.1	9.357	19.978	100.420	8.7	85.7	382	0.123	0.021	35	11.536

99.10	1952	1.507	340	13.7	9.387	19.985	100.192	8.6	85.4	379	0.126	0.021	34	14.111
99.08	1952	1.507	340	12.0	9.409	19.940	100.192	8.6	85.6	383	0.128	0.021	34	12.395
99.07	1952	1.507	340	13.7	9.379	19.955	100.192	8.9	85.9	382	0.125	0.021	34	14.111
99.07	1952	1.507	340	12.0	9.387	19.955	100.192	8.6	85.6	379	0.126	0.021	34	12.395
99.07	1952	1.507	340	13.7	9.372	19.963	100.420	8.7	86.1	380	0.124	0.021	34	14.111
99.05	1951	1.507	340	11.1	9.379	19.970	100.192	8.7	85.6	380	0.125	0.021	34	11.536
99.07	1952	1.507	340	10.3	9.394	20.000	100.192	8.7	85.9	386	0.126	0.020	34	10.678
99.07	1952	1.507	340	12.0	9.379	19.978	100.268	8.7	85.8	379	0.125	0.020	33	12.395
99.07	1951	1.507	340	12.0	9.387	19.963	100.116	8.6	85.8	382	0.126	0.021	34	12.395
99.05	1952	1.507	340	12.0	9.379	19.955	100.344	8.6	85.9	379	0.125	0.021	34	12.395
99.08	1952	1.507	340	12.0	9.394	19.933	100.268	8.8	85.8	378	0.126	0.021	34	12.395
99.05	1951	1.507	340	12.0	9.372	19.985	100.344	8.7	85.8	382	0.124	0.021	34	12.395
99.05	1952	1.507	340	12.0	9.387	19.963	100.116	8.6	85.7	380	0.126	0.021	34	12.395
99.05	1951	1.507	340	11.1	9.365	19.963	100.040	8.9	85.6	384	0.124	0.021	34	11.536
99.02	1951	1.507	340	12.9	9.365	19.955	100.116	8.7	85.9	379	0.124	0.021	34	13.253
99.07	1952	1.507	340	12.0	9.379	19.970	100.116	8.7	85.8	383	0.125	0.021	34	12.395
99.07	1951	1.507	340	11.1	9.379	19.978	100.344	9.0	85.9	378	0.125	0.022	34	11.536
99.05	1952	1.507	340	12.0	9.357	19.978	100.192	8.7	85.6	382	0.123	0.021	34	12.395
99.05	1952	1.507	340	12.0	9.379	19.955	100.344	9.0	85.6	380	0.125	0.021	34	12.395

99.07	1952	1.507	340	11.1	9.387	19.955	99.812	8.8	85.6	379	0.126	0.021	34	11.536
99.07	1952	1.507	340	11.1	9.372	19.955	100.116	8.3	85.6	383	0.124	0.021	34	11.536
99.07	1952	1.507	340	12.0	9.394	19.948	100.192	8.7	85.7	378	0.126	0.021	34	12.395
99.05	1952	1.507	340	12.9	9.387	19.948	99.964	8.7	85.6	378	0.126	0.021	34	13.253
99.07	1952	1.507	340	12.0	9.365	19.955	100.192	8.9	85.9	379	0.124	0.021	35	12.395
99.07	1952	1.507	340	12.9	9.394	19.985	100.192	8.6	85.6	373	0.126	0.022	34	13.253
99.07	1952	1.507	340	12.0	9.387	19.955	100.192	8.6	85.6	379	0.126	0.021	34	12.395
99.84	3061	1.480	407	10.0	10.128	25.624	101.533	7.9	86.4	975	0.116	0.020	34	12.417
99.79	3061	1.480	407	10.9	10.136	25.609	101.533	7.7	85.7	975	0.117	0.020	33	13.275
99.81	3061	1.481	407	10.0	10.113	25.624	101.761	7.9	86.0	975	0.115	0.020	33	12.417
99.82	3061	1.480	407	10.0	10.136	25.632	101.685	8.0	86.2	975	0.117	0.020	33	12.417
99.82	3061	1.481	407	10.0	10.121	25.624	101.761	8.3	86.2	976	0.115	0.021	34	12.417
99.80	3061	1.480	407	10.9	10.121	25.639	101.761	7.9	86.1	974	0.115	0.019	33	13.275
99.78	3061	1.480	407	10.0	10.151	25.595	101.685	7.9	86.2	972	0.118	0.020	34	12.417
99.81	3061	1.480	407	10.0	10.098	25.624	101.761	7.9	86.1	975	0.113	0.020	34	12.417
99.78	3061	1.480	407	10.9	10.106	25.609	101.761	7.9	86.2	973	0.114	0.020	34	13.275
99.78	3061	1.480	407	10.0	10.106	25.624	101.913	8.3	86.3	975	0.114	0.020	34	12.417
99.76	3061	1.480	407	10.0	10.113	25.647	101.533	8.3	86.0	980	0.115	0.020	34	12.417
99.76	3061	1.479	407	9.1	10.121	25.624	101.837	7.9	86.1	972	0.115	0.020	34	11.559

99.77	3061	1.480	407	10.0	10.121	25.580	101.913	7.9	85.9	970	0.115	0.020	34	12.417
99.76	3061	1.480	407	10.0	10.121	25.609	101.685	7.9	86.2	978	0.115	0.020	34	12.417
99.78	3061	1.480	407	10.0	10.128	25.580	101.913	8.2	86.0	973	0.116	0.020	33	12.417
99.75	3061	1.480	407	10.0	10.121	25.624	101.685	7.9	85.9	976	0.115	0.020	33	12.417
99.74	3061	1.480	407	10.0	10.136	25.639	101.685	8.0	86.2	976	0.117	0.020	34	12.417
99.74	3061	1.479	407	10.9	10.136	25.632	101.989	8.0	86.1	974	0.117	0.020	34	13.275
99.79	3061	1.480	407	10.0	10.166	25.617	101.533	8.0	86.2	975	0.120	0.019	34	12.417
99.76	3061	1.479	407	10.9	10.128	25.624	101.761	7.8	86.1	975	0.116	0.020	34	13.275
99.74	3061	1.479	407	10.0	10.121	25.662	101.685	7.8	86.1	975	0.115	0.020	33	12.417
99.73	3061	1.479	407	10.0	10.121	25.617	101.837	7.9	86.1	970	0.115	0.020	34	12.417
99.75	3061	1.479	407	9.1	10.196	25.624	102.065	8.3	86.2	976	0.123	0.019	34	11.559
99.74	3061	1.479	407	10.0	10.128	25.609	101.989	8.4	86.2	974	0.116	0.020	33	12.417
99.73	3061	1.479	407	10.9	10.121	25.647	101.989	8.1	86.2	975	0.115	0.020	33	13.275
99.73	3061	1.479	407	10.0	10.106	25.595	101.533	8.2	86.2	978	0.114	0.019	34	12.417
99.75	3061	1.480	407	10.0	10.113	25.647	101.457	8.2	86.2	974	0.115	0.020	34	12.417
99.72	3061	1.480	407	10.0	10.136	25.632	101.989	8.2	86.2	976	0.117	0.020	34	12.417
99.74	3061	1.479	407	10.0	10.113	25.632	101.989	8.1	86.0	972	0.115	0.019	33	12.417
99.76	3061	1.480	407	9.1	10.143	25.624	101.761	7.9	86.1	973	0.117	0.019	34	11.559
99.78	3061	1.480	407	10.0	10.113	25.647	101.989	8.2	86.0	975	0.115	0.020	33	12.417

99.77	3061	1.480	407	10.9	10.143	25.617	101.913	7.8	86.4	976	0.117	0.020	34	13.275
99.80	3061	1.480	407	10.0	10.091	25.662	101.837	7.8	86.2	975	0.112	0.019	33	12.417
99.79	3061	1.480	407	9.1	10.106	25.617	101.989	8.2	86.5	976	0.114	0.020	34	11.559
99.83	3061	1.480	407	10.0	10.143	25.617	101.609	8.1	86.0	974	0.117	0.021	33	12.417
99.82	3061	1.480	407	10.9	10.136	25.617	101.837	8.2	86.0	979	0.117	0.020	34	13.275
99.79	3061	1.481	407	10.9	10.106	25.617	101.761	7.9	86.0	972	0.114	0.021	34	13.275
99.80	3061	1.480	407	10.9	10.091	25.609	101.989	7.9	86.2	981	0.112	0.020	33	13.275
99.79	3061	1.480	407	10.0	10.113	25.624	101.761	7.7	86.1	975	0.115	0.021	34	12.417
99.76	3061	1.480	407	10.0	10.128	25.609	101.609	7.9	85.9	979	0.116	0.021	34	12.417
99.79	3061	1.480	407	10.0	10.106	25.602	101.685	7.7	86.2	975	0.114	0.021	33	12.417
99.74	3061	1.480	407	10.9	10.098	25.632	101.837	7.9	86.0	979	0.113	0.020	34	13.275
99.78	3061	1.480	407	10.0	10.113	25.609	101.837	7.7	85.9	974	0.115	0.021	34	12.417
99.78	3061	1.480	407	10.0	10.121	25.632	101.913	8.2	86.2	976	0.115	0.020	34	12.417
99.81	3061	1.480	407	10.0	10.128	25.632	101.685	7.9	86.0	978	0.116	0.020	34	12.417
99.78	3061	1.480	407	9.1	10.128	25.624	101.913	8.0	86.0	976	0.116	0.020	34	11.559
99.81	3061	1.480	407	10.0	10.143	25.624	101.837	8.0	86.4	980	0.117	0.020	34	12.417
99.79	3061	1.480	407	10.0	10.136	25.632	101.913	7.9	86.1	974	0.117	0.020	34	12.417
99.82	3061	1.480	407	10.0	10.128	25.602	101.913	8.0	86.0	976	0.116	0.020	33	12.417
99.74	3061	1.480	407	10.9	10.098	25.632	101.837	7.9	86.0	979	0.113	0.020	34	13.275

99.24	4093	1.460	313	10.0	10.227	30.822	99.840	5.7	86.5	1259	0.116	0.021	36	12.414
99.26	4093	1.460	313	10.0	10.257	30.807	100.144	5.5	86.1	1264	0.119	0.023	36	12.414
99.24	4093	1.461	313	10.9	10.242	30.852	99.916	5.5	86.3	1266	0.117	0.022	35	13.272
99.26	4093	1.460	313	11.7	10.235	30.807	99.840	5.4	86.3	1264	0.117	0.022	36	14.130
99.27	4093	1.460	313	10.9	10.242	30.792	99.992	5.8	86.3	1264	0.117	0.022	35	13.272
99.29	4093	1.460	313	10.0	10.272	30.807	100.068	5.6	86.6	1259	0.120	0.021	35	12.414
99.26	4093	1.460	313	12.6	10.257	30.800	99.992	5.6	86.3	1259	0.119	0.021	36	14.988
99.26	4093	1.460	313	10.9	10.242	30.837	99.916	5.8	86.3	1260	0.117	0.020	35	13.272
99.26	4093	1.460	313	11.7	10.242	30.792	100.144	5.4	86.3	1260	0.117	0.022	36	14.130
99.21	4093	1.460	313	11.7	10.249	30.807	99.992	5.6	86.2	1262	0.118	0.020	36	14.130
99.26	4093	1.460	313	10.9	10.287	30.837	100.068	5.7	86.3	1258	0.122	0.021	36	13.272
99.26	4093	1.460	313	10.9	10.257	30.815	100.068	5.8	86.2	1261	0.119	0.020	36	13.272
99.27	4093	1.461	313	11.7	10.249	30.859	100.220	6.0	86.1	1258	0.118	0.021	36	14.130
99.26	4093	1.461	313	11.7	10.249	30.807	99.992	5.5	86.5	1260	0.118	0.022	35	14.130
99.31	4093	1.461	313	12.6	10.249	30.852	100.144	5.5	86.3	1260	0.118	0.021	36	14.988
99.31	4093	1.461	313	11.7	10.272	30.815	100.068	5.7	86.5	1259	0.120	0.021	36	14.130
99.27	4094	1.461	313	9.1	10.257	30.859	99.992	5.7	86.4	1260	0.119	0.022	36	11.555
99.29	4093	1.461	313	11.7	10.257	30.829	100.144	5.5	86.6	1259	0.119	0.022	36	14.130
99.31	4093	1.461	313	10.9	10.264	30.837	100.296	5.8	86.3	1264	0.120	0.022	36	13.272

99.29	4093	1.461	313	10.9	10.272	30.822	100.068	5.9	86.3	1266	0.120	0.020	36	13.272
99.33	4093	1.461	313	10.9	10.272	30.852	100.068	5.7	86.6	1262	0.120	0.020	36	13.272
99.29	4093	1.461	313	11.7	10.264	30.785	100.220	5.9	86.6	1262	0.120	0.022	36	14.130
99.31	4093	1.460	313	10.9	10.264	30.844	100.068	5.5	86.4	1260	0.120	0.021	36	13.272
99.29	4093	1.461	313	10.9	10.257	30.807	99.840	5.8	86.6	1262	0.119	0.021	35	13.272
99.31	4094	1.461	313	10.9	10.242	30.770	100.068	5.7	86.4	1258	0.117	0.021	36	13.272
99.33	4093	1.461	313	10.9	10.279	30.792	100.144	5.6	86.6	1262	0.121	0.021	36	13.272
99.31	4093	1.461	313	11.7	10.294	30.844	100.068	5.6	86.1	1258	0.123	0.022	36	14.130
99.33	4094	1.461	313	10.9	10.294	30.822	100.068	5.7	86.4	1261	0.123	0.022	36	13.272
99.31	4093	1.461	313	10.9	10.235	30.829	99.764	6.0	86.5	1264	0.117	0.023	36	13.272
99.31	4094	1.461	313	12.6	10.249	30.815	100.372	5.5	86.3	1262	0.118	0.021	36	14.988
99.31	4093	1.461	313	11.7	10.242	30.844	99.992	5.5	86.4	1264	0.117	0.022	36	14.130
99.31	4093	1.461	313	11.7	10.235	30.777	99.688	5.4	86.5	1265	0.117	0.020	36	14.130
99.31	4093	1.461	313	11.7	10.257	30.815	99.688	5.5	86.2	1262	0.119	0.022	36	14.130
99.33	4093	1.461	313	10.9	10.227	30.770	100.372	5.5	86.0	1262	0.116	0.021	36	13.272
99.34	4093	1.461	313	10.9	10.249	30.807	99.840	5.5	86.3	1265	0.118	0.021	36	13.272
99.33	4093	1.461	313	10.9	10.227	30.792	99.916	5.9	86.0	1262	0.116	0.022	36	13.272
99.31	4093	1.461	313	11.7	10.249	30.792	99.840	5.4	86.3	1264	0.118	0.022	36	14.130
99.29	4093	1.461	313	11.7	10.227	30.777	100.068	5.3	86.3	1261	0.116	0.021	35	14.130

99.33	4093	1.461	313	10.9	10.272	30.822	99.992	5.4	86.0	1261	0.120	0.022	36	13.272
99.29	4093	1.461	313	10.9	10.242	30.822	100.144	5.5	86.3	1260	0.117	0.022	36	13.272
99.29	4093	1.461	313	10.9	10.220	30.807	99.992	5.5	86.0	1260	0.115	0.022	36	13.272
99.31	4093	1.461	313	11.7	10.227	30.822	99.992	5.5	86.3	1260	0.116	0.022	36	14.130
99.29	4093	1.461	313	10.0	10.220	30.807	99.992	5.3	86.0	1259	0.115	0.022	36	12.414
99.24	4093	1.461	313	10.0	10.287	30.800	99.764	5.5	86.1	1265	0.122	0.021	36	12.414
99.31	4093	1.461	313	11.7	10.257	30.800	100.068	5.2	86.0	1260	0.119	0.021	36	14.130
99.31	4093	1.461	313	10.9	10.257	30.800	99.840	5.6	86.0	1260	0.119	0.022	36	13.272
99.26	4093	1.460	313	10.0	10.242	30.837	99.612	5.5	86.2	1262	0.117	0.021	36	12.414
99.26	4093	1.460	313	10.9	10.249	30.815	100.144	5.5	86.3	1264	0.118	0.020	36	13.272
99.26	4093	1.460	313	10.9	10.264	30.785	100.144	5.5	86.6	1262	0.120	0.021	36	13.272
99.34	4093	1.461	313	10.9	10.249	30.807	99.840	5.5	86.3	1265	0.118	0.021	36	13.272
99.44	4999	1.300	324	19.0	14.198	34.424	98.137	4.4	87.2	2123	0.115	0.019	38	12.385
99.42	4999	1.300	324	19.0	14.213	34.439	98.517	4.7	87.2	2124	0.116	0.021	38	12.385
99.42	4999	1.300	324	19.0	14.198	34.417	98.137	4.4	87.5	2122	0.115	0.019	38	12.385
99.42	4999	1.300	324	19.0	14.183	34.417	98.365	4.8	87.2	2123	0.114	0.019	38	12.385
99.42	4999	1.300	324	19.9	14.213	34.417	98.669	4.5	87.4	2122	0.116	0.020	38	13.243
99.40	4999	1.300	324	20.7	14.228	34.447	98.289	4.3	87.2	2126	0.118	0.019	38	14.101
99.36	4999	1.300	324	19.0	14.257	34.439	98.289	4.8	87.2	2120	0.121	0.020	38	12.385

99.40	4999	1.300	324	19.0	14.228	34.409	98.365	4.8	87.2	2123	0.118	0.021	38	12.385
99.40	4999	1.300	324	19.0	14.220	34.424	98.593	4.5	87.4	2120	0.117	0.021	38	12.385
99.42	4999	1.300	324	19.0	14.220	34.447	97.985	4.6	87.4	2116	0.117	0.020	38	12.385
99.40	4999	1.300	324	19.9	14.213	34.409	98.593	4.8	87.5	2118	0.116	0.020	38	13.243
99.42	4999	1.300	324	19.0	14.220	34.439	98.441	4.7	87.5	2123	0.117	0.019	38	12.385
99.42	4999	1.300	324	19.0	14.228	34.439	98.441	4.6	87.2	2122	0.118	0.020	38	12.385
99.42	4999	1.300	324	19.0	14.213	34.432	98.365	4.6	87.4	2117	0.116	0.020	38	12.385
99.44	4999	1.300	324	19.0	14.213	34.417	98.517	4.6	87.3	2126	0.116	0.019	38	12.385
99.42	4999	1.301	324	19.0	14.228	34.432	98.517	4.9	87.3	2120	0.118	0.021	38	12.385
99.42	4999	1.300	324	18.1	14.235	34.417	98.593	4.8	87.4	2117	0.119	0.019	38	11.527
99.40	4999	1.300	324	19.0	14.235	34.424	98.517	4.7	87.2	2122	0.119	0.020	38	12.385
99.42	4999	1.300	324	18.1	14.213	34.454	98.289	4.3	87.4	2124	0.116	0.020	38	11.527
99.40	4999	1.300	324	19.0	14.235	34.432	98.137	4.7	87.4	2121	0.119	0.019	38	12.385
99.40	4999	1.300	324	18.1	14.220	34.417	98.517	4.8	87.4	2126	0.117	0.019	38	11.527
99.40	4999	1.300	324	19.0	14.235	34.432	98.289	4.6	87.6	2122	0.119	0.019	38	12.385
99.42	4999	1.300	324	19.9	14.235	34.417	98.365	4.5	87.3	2123	0.119	0.020	38	13.243
99.42	4999	1.300	324	19.0	14.213	34.402	98.517	4.5	87.3	2122	0.116	0.020	38	12.385
99.39	4999	1.300	324	19.0	14.220	34.424	98.517	4.6	87.4	2123	0.117	0.019	38	12.385
99.35	4999	1.300	324	19.9	14.213	34.409	98.365	4.7	87.3	2123	0.116	0.020	38	13.243

99.39	4999	1.300	324	18.1	14.243	34.432	98.365	4.8	87.2	2123	0.119	0.020	38	11.527
99.36	4999	1.300	324	19.9	14.235	34.417	98.061	4.6	87.2	2121	0.119	0.020	37	13.243
99.39	4999	1.300	324	20.7	14.220	34.409	98.441	4.3	87.1	2118	0.117	0.019	38	14.101
99.39	4999	1.300	324	19.0	14.213	34.432	98.593	4.4	87.1	2122	0.116	0.020	38	12.385
99.39	4999	1.300	324	18.1	14.220	34.424	98.137	4.8	87.1	2122	0.117	0.019	38	11.527
99.39	4999	1.300	324	19.0	14.220	34.432	97.985	4.6	87.2	2124	0.117	0.019	38	12.385
99.40	4999	1.300	324	18.1	14.213	34.447	98.441	4.7	87.2	2122	0.116	0.019	38	11.527
99.37	4999	1.300	324	19.9	14.213	34.432	98.365	4.6	87.1	2130	0.116	0.021	38	13.243
99.39	4999	1.299	324	19.0	14.243	34.424	98.365	4.6	87.3	2124	0.119	0.020	38	12.385
99.42	4999	1.300	324	19.9	14.220	34.417	98.365	4.6	87.6	2122	0.117	0.019	38	13.243
99.37	4999	1.300	324	19.9	14.235	34.424	98.289	4.7	87.2	2122	0.119	0.020	37	13.243
99.42	4999	1.300	324	19.0	14.205	34.424	98.213	4.5	87.5	2122	0.116	0.020	38	12.385
99.40	4999	1.300	324	19.9	14.228	34.447	98.441	4.6	87.4	2121	0.118	0.020	38	13.243
99.39	4999	1.300	324	19.9	14.205	34.432	98.517	4.6	87.5	2122	0.116	0.021	38	13.243
99.40	4999	1.300	324	18.1	14.205	34.424	98.289	4.8	87.2	2128	0.116	0.019	38	11.527
99.42	4999	1.300	324	19.0	14.228	34.454	98.593	4.3	87.2	2123	0.118	0.019	38	12.385
99.39	4999	1.300	324	19.0	14.235	34.454	98.213	4.6	87.2	2120	0.119	0.019	39	12.385
99.42	4999	1.300	324	19.0	14.213	34.432	98.213	4.8	87.4	2122	0.116	0.020	38	12.385
99.42	4999	1.300	324	19.0	14.257	34.432	98.517	4.6	87.2	2123	0.121	0.019	38	12.385

99.42	4999	1.300	324	19.9	14.213	34.409	98.213	4.8	87.4	2124	0.116	0.020	38	13.243
99.39	4999	1.300	324	19.9	14.228	34.417	98.517	4.7	87.3	2122	0.118	0.020	38	13.243
99.40	4999	1.300	324	19.0	14.198	34.424	98.137	4.6	87.3	2123	0.115	0.021	38	12.385
99.39	4999	1.300	324	19.9	14.220	34.432	98.289	4.4	87.3	2124	0.117	0.021	38	13.243
99.36	4999	1.300	324	19.0	14.213	34.439	98.213	4.6	87.3	2120	0.116	0.020	38	12.385
99.94	5927	1.298	334	5.0	13.992	38.624	99.037	4.2	88.2	1689	0.116	0.021	38	12.324
99.97	5927	1.298	334	5.9	14.015	38.684	98.885	4.1	88.1	1688	0.118	0.021	38	13.182
99.97	5927	1.298	334	6.7	14.007	38.647	98.961	4.4	88.2	1684	0.117	0.021	38	14.040
99.96	5927	1.298	334	6.7	14.030	38.602	98.885	4.4	88.4	1685	0.120	0.020	38	14.040
99.96	5927	1.298	334	6.7	14.007	38.624	98.809	4.3	88.4	1685	0.117	0.022	37	14.040
99.96	5927	1.298	334	6.7	14.037	38.624	99.189	4.4	88.4	1688	0.120	0.021	37	14.040
99.95	5927	1.298	334	5.9	14.007	38.632	98.961	4.4	88.2	1683	0.117	0.021	37	13.182
99.95	5927	1.298	334	5.0	14.022	38.639	98.809	4.7	88.4	1686	0.119	0.020	37	12.324
99.95	5927	1.298	334	5.9	13.992	38.624	98.809	4.5	88.6	1694	0.116	0.021	37	13.182
99.95	5927	1.298	334	5.9	14.022	38.624	99.189	4.5	88.3	1688	0.119	0.020	37	13.182
99.98	5927	1.298	334	6.7	14.015	38.632	99.341	4.3	88.2	1688	0.118	0.021	37	14.040
100.00	5927	1.298	334	6.7	14.022	38.654	98.961	4.2	88.5	1686	0.119	0.022	38	14.040
99.97	5927	1.298	334	6.7	13.992	38.654	98.581	4.4	88.4	1686	0.116	0.021	38	14.040
99.97	5927	1.299	334	5.9	14.030	38.647	98.885	4.4	88.6	1690	0.120	0.021	38	13.182

100.00	5927	1.299	334	7.6	14.007	38.647	98.961	4.4	88.5	1690	0.117	0.022	37	14.899
100.00	5927	1.298	334	6.7	14.022	38.654	99.037	4.4	88.1	1689	0.119	0.020	38	14.040
99.92	5927	1.298	334	5.9	14.007	38.647	98.733	4.4	88.5	1689	0.117	0.022	37	13.182
99.97	5927	1.298	334	5.9	14.000	38.647	98.809	4.6	88.2	1688	0.117	0.020	38	13.182
99.98	5927	1.298	334	5.9	14.000	38.654	99.037	4.6	88.4	1688	0.117	0.021	37	13.182
99.94	5927	1.298	334	5.9	14.015	38.662	99.037	4.4	88.4	1688	0.118	0.022	38	13.182
99.95	5927	1.298	334	5.0	14.015	38.654	98.809	4.4	88.4	1686	0.118	0.020	38	12.324
99.91	5927	1.298	334	6.7	14.000	38.639	99.037	4.4	88.4	1694	0.117	0.021	37	14.040
99.96	5927	1.298	334	6.7	14.007	38.632	98.657	4.2	88.4	1686	0.117	0.022	37	14.040
99.92	5927	1.298	334	5.9	13.992	38.662	99.037	4.4	88.4	1690	0.116	0.021	38	13.182
99.94	5927	1.298	334	5.9	13.992	38.632	98.809	4.4	88.3	1692	0.116	0.022	38	13.182
99.94	5927	1.298	334	6.7	13.985	38.654	98.733	4.5	88.6	1690	0.115	0.021	38	14.040
99.92	5927	1.298	334	5.0	14.037	38.654	98.885	4.5	88.5	1690	0.120	0.022	38	12.324
99.91	5927	1.298	334	5.9	14.015	38.654	98.885	4.4	88.5	1688	0.118	0.022	38	13.182
99.90	5927	1.298	334	5.9	13.985	38.669	99.113	4.2	88.4	1688	0.115	0.021	37	13.182
99.91	5927	1.298	334	5.0	14.022	38.624	98.885	4.4	88.6	1691	0.119	0.021	38	12.324
99.94	5927	1.298	334	5.9	14.000	38.676	98.733	4.4	88.4	1686	0.117	0.021	38	13.182
99.97	5927	1.298	334	6.7	14.022	38.647	98.733	4.3	88.5	1686	0.119	0.022	38	14.040
99.96	5927	1.298	334	5.9	14.007	38.632	98.733	4.4	88.6	1691	0.117	0.021	38	13.182

99.93	5927	1.298	334	5.9	14.022	38.669	98.961	4.2	88.4	1689	0.119	0.019	38	13.182
99.96	5927	1.298	334	5.9	14.022	38.639	98.809	4.4	88.4	1692	0.119	0.022	38	13.182
99.96	5927	1.298	334	5.9	14.037	38.632	98.961	4.5	88.7	1689	0.120	0.022	37	13.182
99.92	5927	1.298	334	5.9	14.015	38.647	98.809	4.2	88.6	1692	0.118	0.021	37	13.182
99.94	5927	1.298	334	5.0	14.030	38.647	99.189	4.5	88.4	1689	0.120	0.021	37	12.324
99.94	5927	1.298	334	5.9	14.022	38.639	99.113	4.7	88.4	1688	0.119	0.021	38	13.182
99.92	5927	1.298	334	5.9	14.045	38.632	98.885	4.3	88.4	1688	0.121	0.021	37	13.182
99.94	5927	1.299	334	5.9	14.022	38.654	99.037	4.7	88.6	1684	0.119	0.021	38	13.182
99.97	5927	1.298	334	5.9	14.015	38.647	98.885	4.5	88.6	1682	0.118	0.022	37	13.182
99.93	5927	1.298	334	5.9	14.022	38.676	98.961	4.4	88.4	1689	0.119	0.021	37	13.182
99.96	5927	1.298	334	5.9	14.045	38.669	98.961	4.1	88.3	1684	0.121	0.021	37	13.182
99.97	5927	1.298	334	5.9	14.030	38.654	99.037	4.4	88.6	1688	0.120	0.021	37	13.182
100.00	5927	1.298	334	5.9	14.022	38.662	99.113	4.5	88.4	1686	0.119	0.021	37	13.182
99.97	5927	1.298	334	6.7	13.992	38.654	99.037	4.3	88.3	1686	0.116	0.021	38	14.040
100.00	5927	1.299	334	5.9	14.015	38.647	98.809	4.6	88.6	1685	0.118	0.020	37	13.182
99.98	5927	1.298	334	6.7	14.030	38.632	98.809	4.5	88.2	1688	0.120	0.021	37	14.040
100.00	5927	1.299	334	6.7	14.022	38.632	99.037	4.4	88.4	1690	0.119	0.021	37	14.040

3.3 Test groups data to develop two-stage models

Name:	AFR	AMass	FAPW	Hydrogen Volume _fraction	IAdv	Inj_End	L	La_1	N	NOx	Torque	test_ groupings
Unit:	afr	mg/ms	ms	%	Degree BTDC	Degree CA	%	Lambda	RPM	ppt	N.m	number
Data:	61.35	16.22	7.07	26.32	20	285	0.268	1.79	1472	0.432	68.01	1
	61.06	16.22	7.00	26.53	19	285	0.263	1.78	1472	0.400	69.62	1
	61.27	16.12	7.01	26.56	17	285	0.263	1.78	1472	0.343	69.68	1
	61.40	16.22	6.99	26.46	15	285	0.263	1.79	1472	0.295	69.62	1
	61.59	16.22	6.99	26.46	12	285	0.263	1.79	1472	0.237	69.40	1
	61.45	16.22	7.00	26.46	10	285	0.263	1.79	1472	0.206	68.91	1
	61.42	16.22	6.99	26.50	8	285	0.263	1.79	1472	0.176	68.00	1

	61.45	16.12	6.99	26.56	5	285	0.263	1.79	1472	0.147	66.40	1
	61.48	16.22	7.05	26.38	3	285	0.266	1.79	1472	0.130	63.70	1
	61.64	16.32	7.11	26.39	0	285	0.271	1.80	1472	0.132	59.60	1
	58.42	17.47	7.34	25.20	20	315	0.261	1.70	2024	0.359	56.42	2
	58.32	17.37	7.34	25.29	19	315	0.261	1.70	2024	0.332	57.05	2
	58.42	17.47	7.34	25.20	17	315	0.261	1.70	2024	0.284	57.67	2
	59.04	17.47	7.35	25.13	15	315	0.261	1.72	2024	0.244	58.23	2
	58.25	17.47	7.34	25.23	12	315	0.261	1.70	2024	0.199	58.69	2
	58.46	17.47	7.36	25.17	10	315	0.262	1.70	2024	0.175	58.88	2
	58.59	17.47	7.37	25.15	8	315	0.262	1.71	2024	0.155	58.54	2
	58.59	17.37	7.37	25.21	5	315	0.262	1.71	2024	0.131	57.32	2
	58.46	17.47	7.38	25.15	3	315	0.263	1.70	2024	0.120	54.85	2
	57.18	18.08	7.36	24.99	20	360	0.258	1.67	3073	0.676	39.49	3
	57.18	18.08	7.39	24.95	19	360	0.258	1.67	3073	0.648	39.82	3
	57.18	18.08	7.38	24.96	17	360	0.258	1.67	3073	0.600	40.13	3
	57.18	18.08	7.35	25.01	15	360	0.257	1.67	3073	0.561	40.41	3
	57.18	18.18	7.38	24.89	12	360	0.258	1.67	3073	0.515	40.58	3
	57.18	17.98	7.38	25.02	10	360	0.258	1.67	3073	0.491	40.54	3
	57.18	18.08	7.36	24.98	8	360	0.258	1.67	3073	0.471	40.11	3

	57.18	18.08	7.37	24.97	5	360	0.258	1.67	3073	0.448	39.03	3
	57.18	18.08	7.37	24.97	3	360	0.258	1.67	3073	0.436	36.97	3
	57.18	18.08	7.37	24.98	0	360	0.258	1.67	3073	0.422	33.57	3
	57.73	16.18	8.15	24.97	20	300	0.503	1.68	1465	0.431	81.11	4
	57.73	16.28	8.16	24.89	19	300	0.503	1.68	1465	0.403	81.61	4
	57.73	16.28	8.15	24.90	17	300	0.503	1.68	1465	0.355	81.97	4
	57.73	16.28	8.16	24.89	15	300	0.503	1.68	1465	0.316	81.96	4
	57.73	16.28	8.16	24.89	12	300	0.503	1.68	1465	0.270	81.31	4
	57.73	16.18	8.16	24.96	10	300	0.503	1.68	1465	0.246	79.57	4
	57.73	16.28	8.16	24.88	8	300	0.503	1.68	1465	0.226	77.45	4
	57.73	16.28	8.16	24.89	5	300	0.503	1.68	1459	0.203	73.23	4
	57.73	16.18	8.16	24.95	3	300	0.503	1.68	1465	0.191	69.88	4
	57.73	16.28	8.15	24.89	0	300	0.503	1.68	1459	0.177	70.10	4
	55.47	19.72	8.37	22.67	20	325	0.502	1.62	2029	0.376	90.75	5
	55.47	19.82	8.37	22.62	19	325	0.502	1.62	2029	0.348	92.41	5
	55.47	19.62	8.36	22.73	17	325	0.502	1.62	2029	0.301	94.12	5
	55.47	19.62	8.37	22.72	15	325	0.502	1.62	2029	0.261	95.82	5
	55.47	19.62	8.37	22.72	12	325	0.502	1.62	2029	0.215	97.23	5
	55.47	19.62	8.37	22.72	10	325	0.502	1.62	2029	0.191	98.26	5

	55.47	19.62	8.36	22.72	8	325	0.502	1.62	2029	0.171	98.25	5
	55.47	19.62	8.36	22.72	5	325	0.502	1.62	2029	0.148	96.70	5
	55.47	19.62	8.36	22.73	3	325	0.502	1.62	2029	0.136	93.19	5
	55.47	19.72	8.36	22.68	0	325	0.502	1.62	2029	0.122	87.71	5
	57.98	23.78	8.55	20.70	20	380	0.503	1.69	3031	0.456	82.30	6
	57.98	23.60	8.56	20.76	19	380	0.501	1.69	3031	0.428	82.43	6
	57.98	23.93	8.60	20.60	17	380	0.503	1.69	3032	0.380	82.54	6
	57.98	23.49	8.55	20.81	15	380	0.501	1.69	3031	0.341	82.61	6
	57.98	23.72	8.59	20.69	12	380	0.502	1.69	3031	0.295	82.57	6
	57.98	23.60	8.57	20.75	10	380	0.502	1.69	3031	0.271	82.33	6
	57.98	23.80	8.56	20.69	8	380	0.501	1.69	3031	0.251	81.71	6
	57.98	23.72	8.58	20.69	5	380	0.503	1.69	3031	0.228	80.86	6
	57.98	23.61	8.57	20.74	3	380	0.501	1.69	3031	0.216	79.44	6
	57.98	23.88	8.55	20.67	0	380	0.503	1.69	3031	0.202	76.27	6
	67.86	28.52	7.70	18.72	25	407	0.504	1.98	4045	0.231	82.29	7
	67.86	28.42	7.70	18.75	24	407	0.504	1.98	4045	0.209	83.24	7
	67.86	28.42	7.69	18.75	23	407	0.504	1.98	4045	0.188	84.28	7
	67.86	28.42	7.70	18.75	22	407	0.504	1.98	4045	0.170	85.31	7
	67.86	28.42	7.70	18.75	20	407	0.504	1.98	4045	0.138	86.34	7

	67.86	28.52	7.70	18.72	19	407	0.504	1.98	4045	0.124	87.14	7
	67.86	28.42	7.70	18.75	17	407	0.504	1.98	4045	0.100	87.48	7
	67.86	28.42	7.70	18.74	15	407	0.504	1.98	4045	0.081	87.04	7
	67.86	28.52	7.70	18.72	12	407	0.504	1.98	4045	0.057	85.50	7
	67.86	28.52	7.70	18.72	10	407	0.504	1.98	4045	0.045	83.20	7
	50.95	17.12	8.74	24.40	20	285	0.748	1.48	1489	1.839	89.81	8
	50.95	16.72	8.74	24.64	19	285	0.749	1.48	1489	1.726	91.01	8
	50.95	17.02	8.76	24.43	17	285	0.748	1.48	1489	1.624	92.21	8
	50.95	16.72	8.76	24.61	15	285	0.749	1.48	1489	1.531	93.41	8
	50.95	17.02	8.76	24.42	12	285	0.748	1.48	1489	1.371	94.45	8
	50.95	17.02	8.76	24.42	10	285	0.748	1.48	1489	1.302	95.05	8
	50.95	16.92	8.76	24.49	8	285	0.748	1.48	1495	1.182	94.41	8
	50.95	16.92	8.75	24.50	5	285	0.749	1.48	1489	1.084	93.12	8
	50.95	16.72	8.75	24.62	3	285	0.749	1.48	1489	0.969	89.18	8
	50.95	16.92	8.75	24.51	0	285	0.748	1.48	1489	0.909	84.94	8
	52.28	20.12	8.88	22.42	20	310	0.748	1.52	2029	1.330	96.23	9
	52.28	20.22	8.87	22.38	19	310	0.748	1.52	2029	1.267	97.94	9
	52.28	20.02	8.87	22.47	17	310	0.748	1.52	2029	1.155	99.74	9
	52.28	19.92	8.87	22.52	15	310	0.747	1.52	2029	1.052	101.64	9

	52.28	20.02	8.87	22.48	12	310	0.748	1.52	2029	0.892	107.19	9
	52.28	20.12	8.87	22.43	10	310	0.748	1.52	2029	0.803	106.18	9
	52.28	20.12	8.87	22.43	8	310	0.748	1.52	2029	0.705	105.27	9
	52.28	20.12	8.87	22.43	5	310	0.748	1.52	2029	0.595	103.81	9
	52.28	20.12	8.87	22.43	3	310	0.748	1.52	2029	0.500	101.04	9
	52.28	20.02	8.87	22.48	0	310	0.748	1.52	2029	0.430	95.81	9
	50.88	25.22	9.61	20.30	20	380	0.747	1.48	3055	2.539	102.63	10
	50.88	25.12	9.60	20.34	19	380	0.747	1.48	3055	2.490	102.87	10
	50.88	25.22	9.60	20.31	17	380	0.747	1.48	3055	2.412	103.08	10
	50.88	25.22	9.60	20.31	15	380	0.747	1.48	3055	2.340	103.31	10
	50.89	25.42	9.60	20.25	12	380	0.747	1.48	3055	2.225	103.41	10
	50.89	25.12	9.60	20.33	10	380	0.747	1.48	3055	2.154	103.28	10
	50.89	25.23	9.60	20.31	8	380	0.747	1.48	3055	2.076	102.61	10
	50.89	25.23	9.60	20.31	5	380	0.747	1.48	3055	1.969	101.61	10
	50.89	25.22	9.60	20.31	3	380	0.747	1.48	3055	1.889	99.54	10
	50.89	25.12	9.60	20.33	0	380	0.747	1.48	3055	1.788	95.90	10
	53.50	29.72	10.58	18.16	20	460	0.742	1.56	4039	1.330	111.40	11
	53.50	29.63	10.58	18.18	19	460	0.742	1.56	4039	1.210	112.28	11
	53.50	29.82	10.58	18.14	17	460	0.742	1.56	4039	1.111	113.26	11

	53.50	29.83	10.58	18.14	15	460	0.742	1.56	4039	0.995	114.04	11
	53.50	29.72	10.58	18.16	12	460	0.742	1.56	4039	0.934	114.14	11
	53.50	29.83	10.58	18.14	10	460	0.743	1.56	4039	0.863	113.64	11
	53.50	29.73	10.58	18.16	8	460	0.744	1.56	4039	0.795	113.60	11
	53.50	29.73	10.59	18.16	5	460	0.744	1.56	4039	0.674	112.90	11
	53.50	29.73	10.59	18.15	3	460	0.744	1.56	4039	0.576	112.65	11
	53.50	29.73	10.59	18.15	0	460	0.744	1.56	4039	0.459	110.14	11
	48.65	16.52	9.79	24.14	20	310	0.993	1.42	1447	1.935	95.00	12
	48.65	16.62	9.79	24.09	19	310	0.994	1.42	1435	1.797	97.79	12
	48.65	16.52	9.79	24.15	17	310	0.994	1.42	1441	1.558	99.37	12
	48.65	16.52	9.79	24.15	15	310	0.993	1.42	1441	1.362	100.04	12
	48.65	16.52	9.79	24.14	12	310	0.994	1.42	1435	1.131	98.46	12
	48.65	16.32	9.79	24.27	10	310	0.994	1.42	1435	1.011	96.46	12
	48.65	16.62	9.79	24.09	8	310	0.994	1.42	1435	0.912	93.80	12
	48.65	16.32	9.79	24.26	5	310	0.994	1.42	1441	0.796	91.42	12
	48.65	16.52	9.79	24.15	3	310	0.994	1.42	1435	0.736	89.15	12
	48.65	16.32	9.79	24.26	0	310	0.994	1.42	1441	0.665	86.79	12
	51.72	20.32	9.39	22.04	15	340	0.990	1.51	1981	0.495	102.17	13
	51.72	19.93	9.38	22.22	12	340	0.990	1.51	1951	0.379	105.70	13

	51.72	20.72	9.42	21.84	10	340	0.990	1.51	2071	0.319	102.34	13
	51.72	20.43	9.40	21.99	8	340	0.990	1.51	2017	0.270	101.77	13
	51.72	18.93	9.36	22.71	5	340	0.991	1.51	2051	0.212	99.61	13
	51.72	19.13	9.35	22.62	3	340	0.990	1.51	2053	0.181	98.59	13
	50.81	25.02	10.10	20.02	15	407	0.998	1.48	3031	1.352	103.18	14
	50.81	25.12	10.12	19.98	14	407	0.997	1.48	3055	1.262	103.16	14
	50.81	25.62	10.13	19.84	13	407	0.998	1.48	3061	1.178	103.68	14
	50.81	25.22	10.14	19.94	12	407	0.998	1.48	3073	1.099	103.76	14
	50.81	25.62	10.13	19.84	10	407	0.998	1.48	3061	0.975	104.25	14
	50.81	25.52	10.13	19.87	7	407	0.997	1.48	3061	0.867	103.58	14
	50.81	25.72	10.13	19.81	3	407	0.997	1.48	3067	0.842	101.60	14
	50.81	25.62	10.13	19.84	0	407	0.997	1.48	3061	0.925	99.58	14
	50.14	30.83	10.24	18.68	20	313	0.993	1.46	4093	1.885	118.71	16
	50.14	30.92	10.25	18.65	19	313	0.993	1.46	4099	1.654	118.83	16
	50.14	30.93	10.24	18.66	17	313	0.992	1.46	4093	1.534	119.28	16
	50.14	30.92	10.23	18.67	15	313	0.992	1.46	4093	1.435	119.54	16
	50.14	30.93	10.23	18.66	12	313	0.992	1.46	4093	1.319	119.75	16
	50.14	30.82	10.23	18.68	10	313	0.992	1.46	4093	1.259	119.85	16
	50.14	30.92	10.22	18.67	8	313	0.992	1.46	4093	1.188	119.76	16

	50.14	30.92	10.22	18.67	5	313	0.993	1.46	4087	1.151	119.48	16
	50.14	30.93	10.22	18.67	3	313	0.992	1.46	4093	1.135	118.35	16
	50.14	31.03	10.22	18.65	0	313	0.993	1.46	4087	1.107	118.45	16
	44.64	34.03	14.18	18.06	20	323	0.994	1.30	4951	2.354	103.37	17
	44.64	34.42	14.20	18.01	19	324	0.994	1.30	4999	2.123	102.71	17
	44.64	34.73	14.21	17.97	17	324	0.993	1.30	5017	2.003	102.67	17
	44.64	34.72	14.23	17.97	15	325	0.993	1.30	5077	1.904	101.72	17
	44.64	35.13	14.25	17.92	12	325	0.993	1.30	5113	1.788	101.15	17
	44.64	35.02	14.24	17.93	10	325	0.993	1.30	5113	1.728	101.07	17
	44.64	35.12	14.24	17.92	8	325	0.993	1.30	5107	1.657	100.70	17
	44.64	34.92	14.24	17.94	5	325	0.994	1.30	5107	1.620	99.58	17
	44.64	35.03	14.24	17.93	3	325	0.993	1.30	5107	1.604	98.05	17
	44.64	35.03	14.24	17.93	0	325	0.994	1.30	5107	1.576	97.84	17
	44.57	36.83	13.82	17.70	12	331	0.998	1.30	5931	2.024	86.52	18
	44.57	37.33	13.89	17.64	10	331	0.998	1.30	5905	1.904	87.93	18
	44.57	37.72	13.94	17.59	8	333	0.998	1.30	5913	1.805	88.02	18
	44.57	38.62	13.99	17.49	5	334	0.999	1.30	5927	1.689	88.64	18
	44.57	38.63	14.02	17.48	3	335	0.998	1.30	5999	1.628	87.18	18
	44.57	38.72	14.14	17.44	0	335	0.998	1.30	5923	1.557	86.32	18

4 APPENDIX 4: SOFTWARES

All the softwares that were developed and used in this PhD project included:

4.1 UTAS ANNs software package

4.2 Developed ANNs and ANFIS program in MATLAB environment for electrolyser prediction

4.3 Labview program for deionized water

4.4 Fuzzy expert system and 136 rules

4.5 Developed ANNs program in MATLAB environment for emission prediction software

4.6 Two-stage modelling system and generated results in Simulink, CAGE, and MATLAB files

4.7 Basic tuning excel calculation tool for hydrogen car